Design of Shallow Foundations.

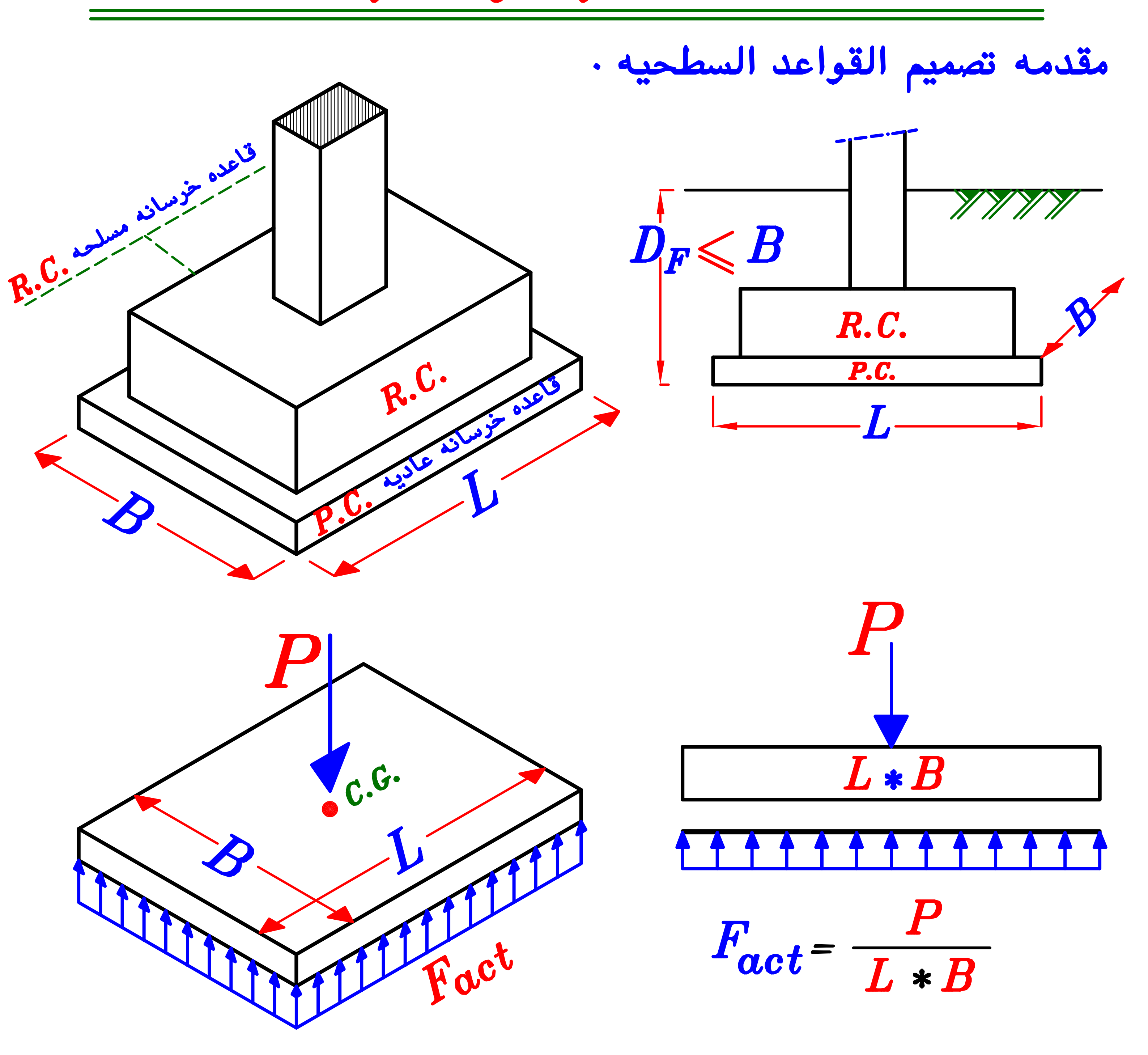
تصميم القواعد السطحيه

نسألكم الدعاء

نتقدم بالشكر للمهندس / محمد ماهر توفيق .

Table of Contents.

مقدمه تصميم القواعد السطحيه .



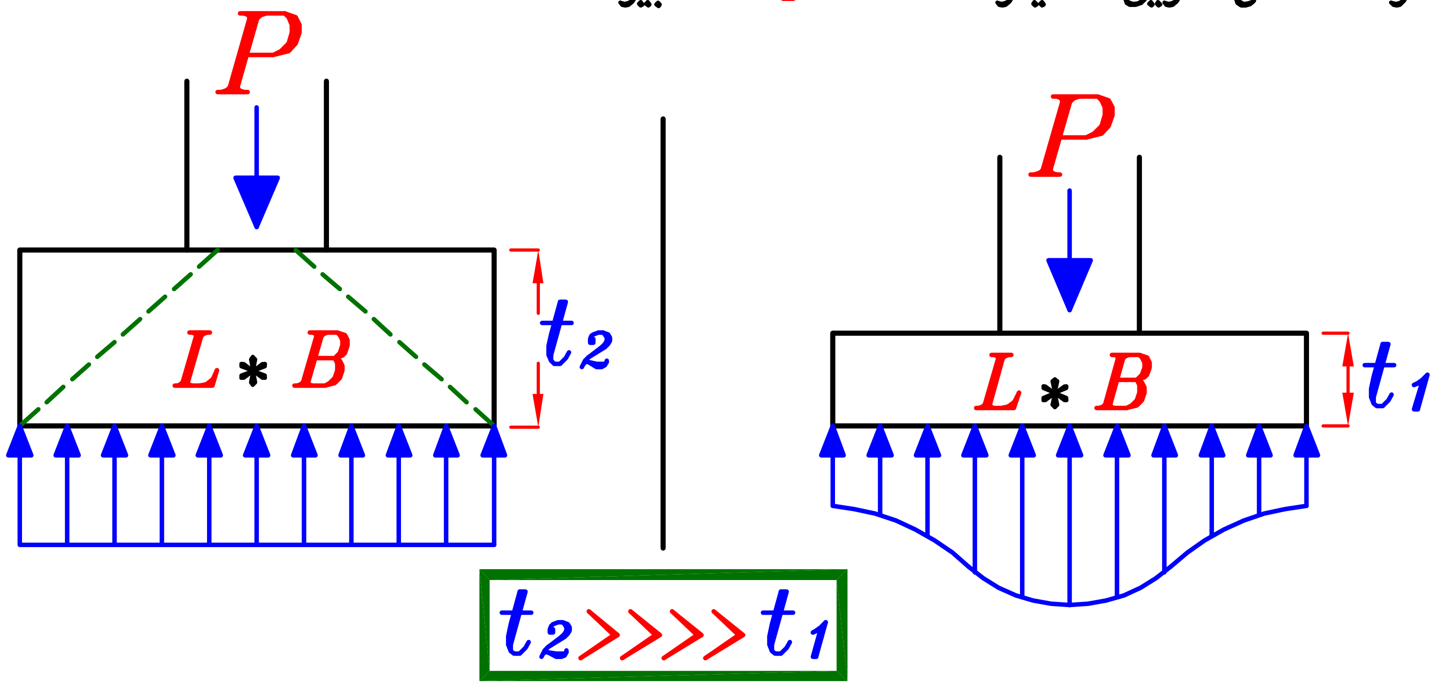
$$F_{act} = \frac{P}{L * B}$$

الهدف من استخدام القواعد السطحيه (*Shallow Foundations*)
هو تحويل حمل (*Load*) العمود المركز الى اجهاد منتظم (*uniform stress*) على التربه .
و ذلك لانه من الافضل لتربه التأسيس تحمل اجهادات منتظمه (*uniform stresses*)
عن تحمل أحمال مركزه (*Concentrated Loads*) من الاعمده .
و ذلك لتفادى حدوث اختراق (*punching*) للعمود داخل التربه .

المبدأ الأساسى فى تصميم القواعد السطحيه .

يعتمد التصميم البسيط للقواعد السطحيه على عمل اجهاد منتظم (*uniform stresses*) على القواعد يمثل رد فعل تربه التأسيس .

و لتحقيق ذلك يجب أن تكون القاعده جاسئه (*Rigid Footing*)
و ذلك عن طريق اختيار سُمك (*depth*) كبير للقاعده .



Footing (1)

Flexible Footing

- Area $L * B$
- Column Load P

Non-Uniform contact stress.

Footing (2)

Rigid Footing

- Area $L * B$
- Column Load P

Uniform contact stress.

لعمل قاعده جاسئه (*Rigid Footing*) يجب اختيار (*depth*) كبير للقاعده .

توجد عده أنواع و أشكال للقواعد السطحيه يتم اختيارها تبعا ل :-

١- شكل العمود أو الحائط المحمول على القاعده .

٢- الحمل على العمود و المسافات بين الاعمده .

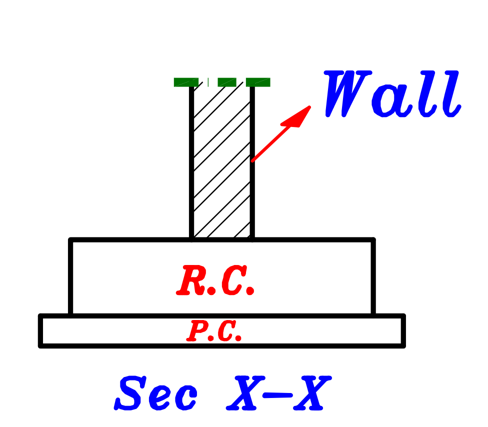
٣- وجود حد جار (*property Line*) بجوار الاعمده .

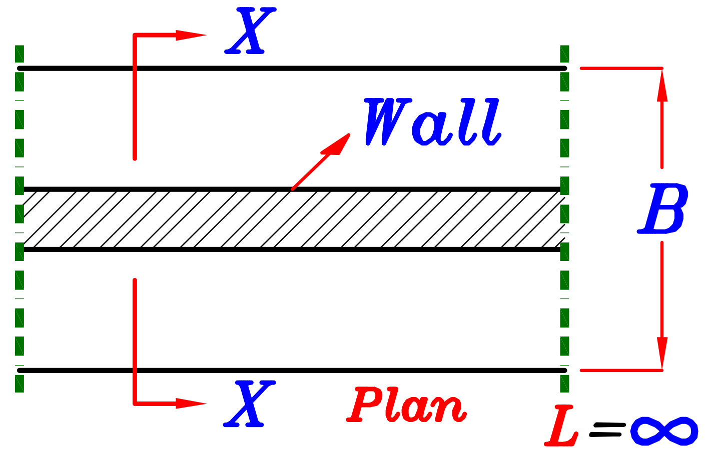
Types of Shallow Foundations.

أنواع القواعد السطحيه .

1- *Strip Footing.* القواعد الشريطيه

- هى قواعد طوليه لحمل الحوائط السانده و الاسوار .





2- *Isolated Footing.* القواعد المنفصله

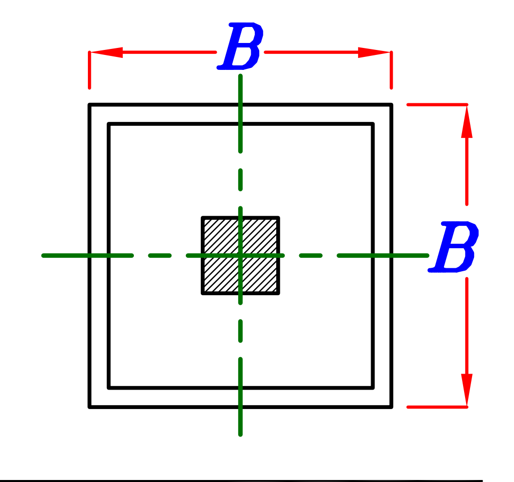
- هى قواعد ذات مساحه محدده ($L * B$) تنفذ لتحمل عمود واحد فقط.

و لها اشكال مختلفه منها :-

a- *Squared Isolated Footing.* قواعد مربعه

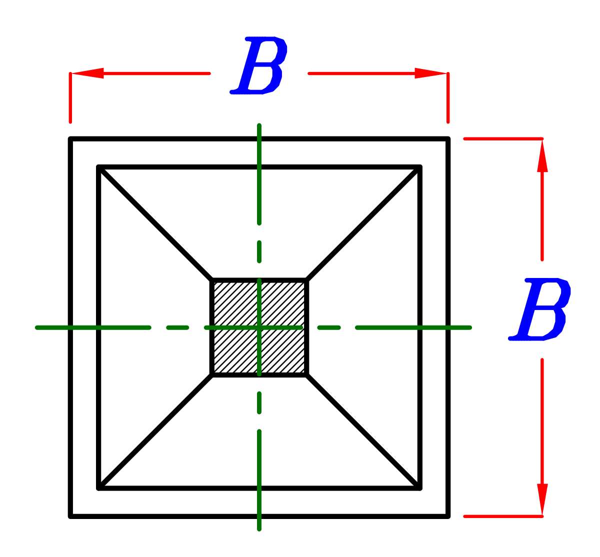
- تستخدم فى حاله :

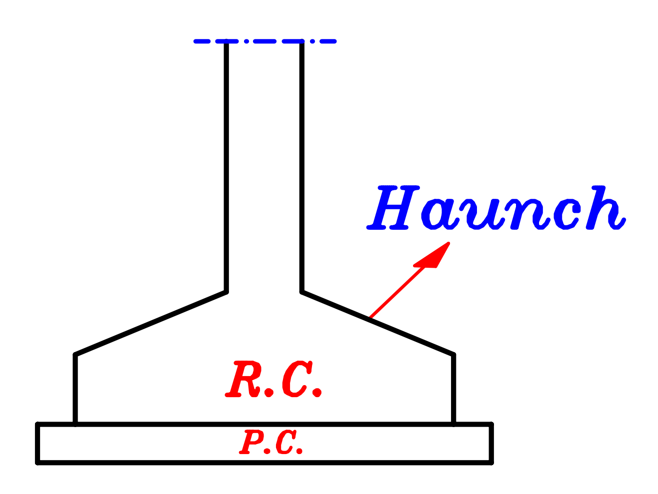
- عمود مربع .
- عمود دائرى .
- يُمكن مع الاعمده المستطيله لكنه غير مفضل .



b – Haunched Square Isolated Footing.

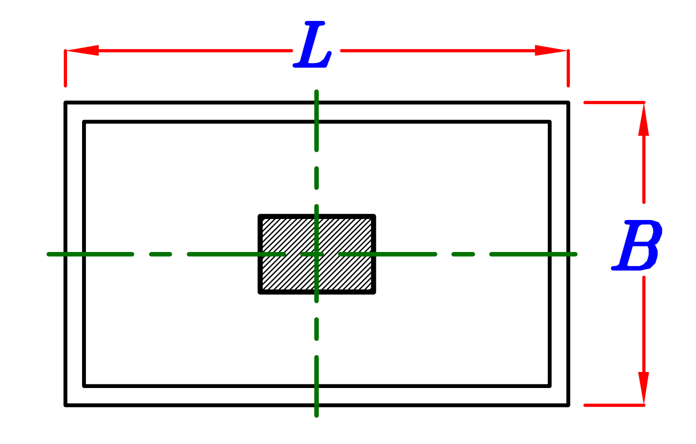
- هى قواعد منفصله ذات سُمك متغير كبير عند العمود و يقل عند الاطراف .
و تستخدم مع الاعمده ذات الاحمال الكبيره جدا مثل اعمده الكبارى .





c – Rectangular Isolated Footing. قواعد مستطيله

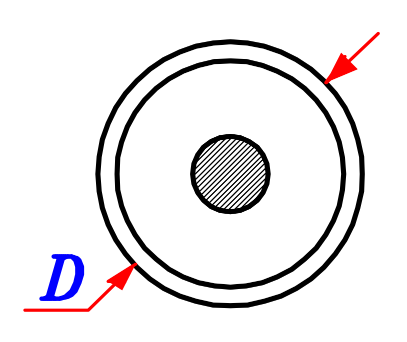
- تستخدم فى حاله :
- الاعمده المستطيله .
- يُمكن مع الاعمده المربعه لكنه غير مفضل .



d – Circular Isolated Footing. قواعد دائريه

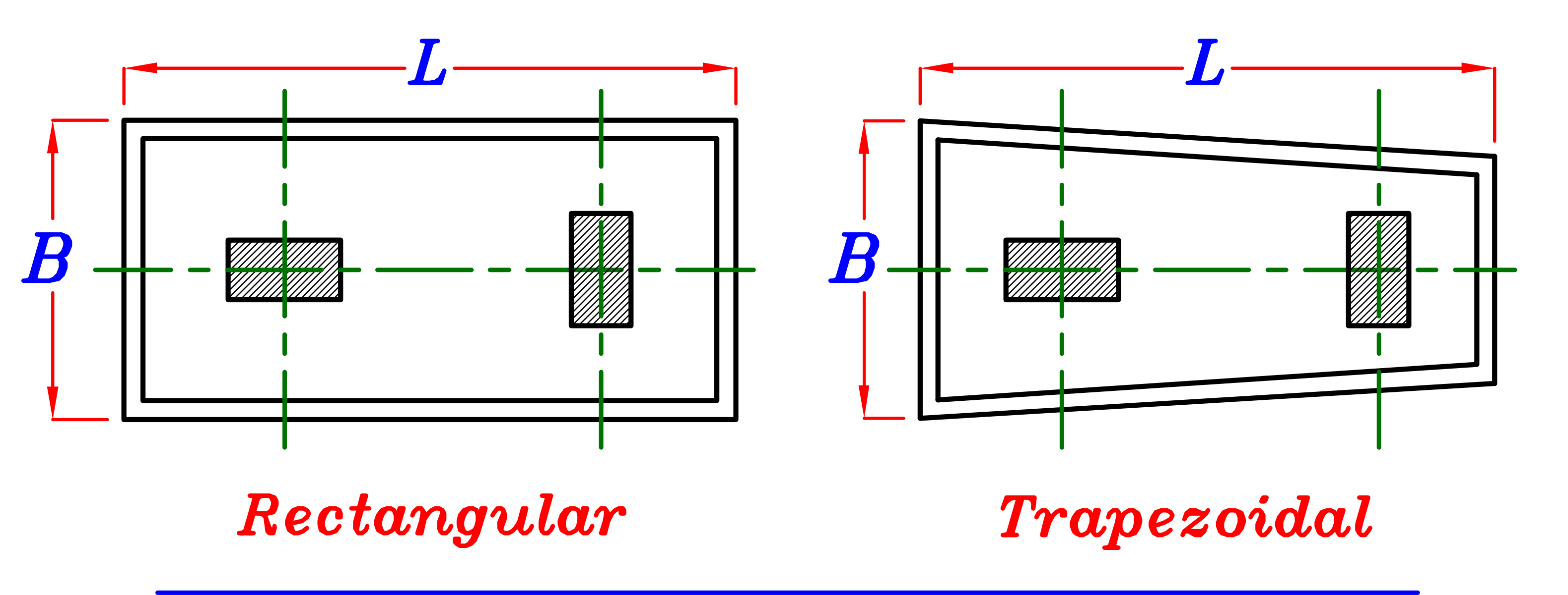
- تستخدم فقط مع الاعمده الدائريه .

* و هى صعبه و مكلفه فى التنفيذ لذلك يستخدم بدلا منها القواعد المربعه .



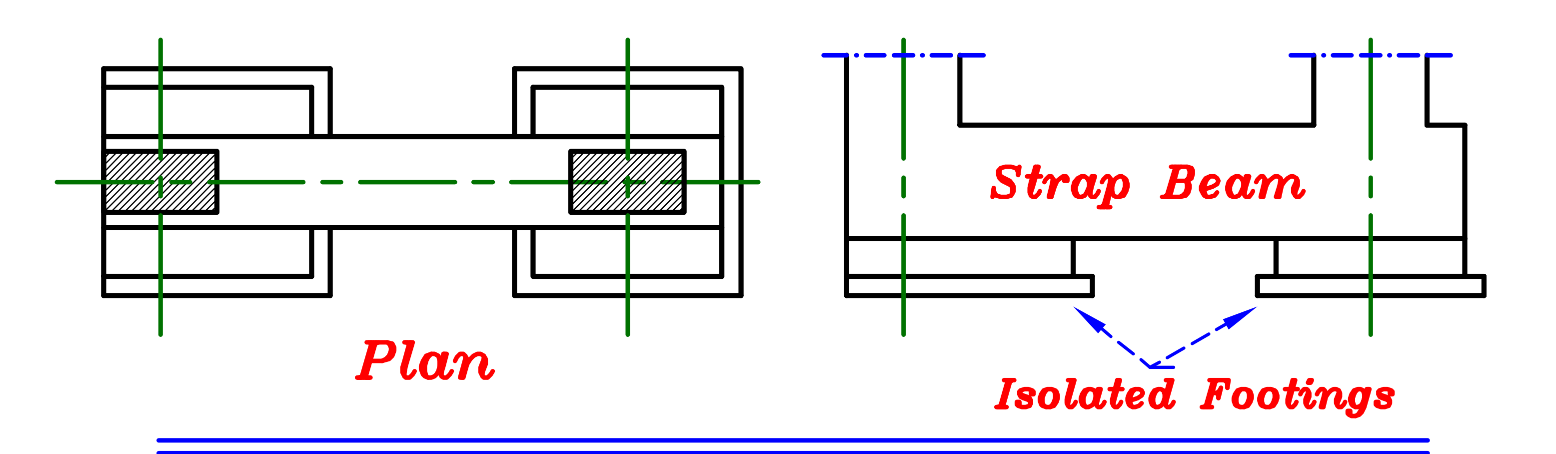
3- Combined Footing. القواعد المشتركه

• هى قواعد تحمل عمودين أو أكثر و لها شكلان :-



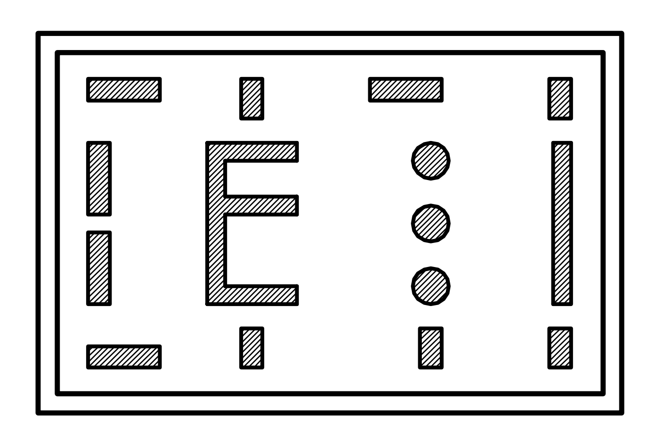
4- Strap Beam.

• هى كمره عميقه (مقلوبه) تحمل عمودين و تربطهما سويا ثم ترتكز على قاعدتين منفصلتين .



5-Raft. (اللبشه)

• هى قاعده واحده تتحمل جميع أعمده المنشأ بكافه أشكال الاعمده و كذلك ال Cores , Shear Walls

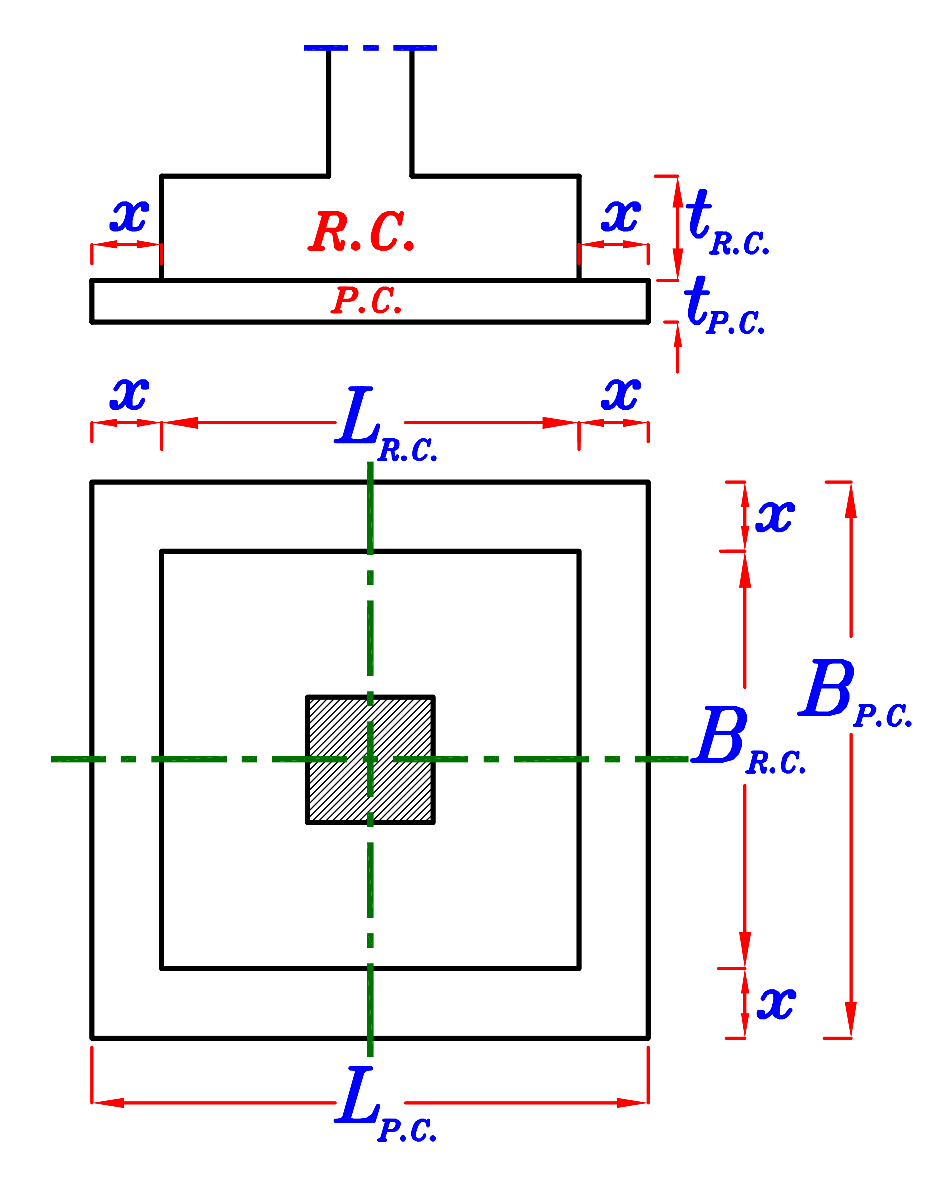


Components Of Shallow Foundations.

دائما تتكون أى قاعده من جزئين :-

1- Plain Concrete Footing. (P.C.)

2- Reinforced Concrete Footing. (R.C.)



* وظيفه القاعده العاديه (P.C.) :-

١- تكون بمثابه فرشه أسفل القاعده المسلحه لضمان تسويه السطح الذى سوف يُرص عليه حديد التسليح و كذلك ليكون الحديد بعيدا عن حبيبات التربه لما قد تحمله التربه من أملاح قد تؤدى الى صدأ الحديد.

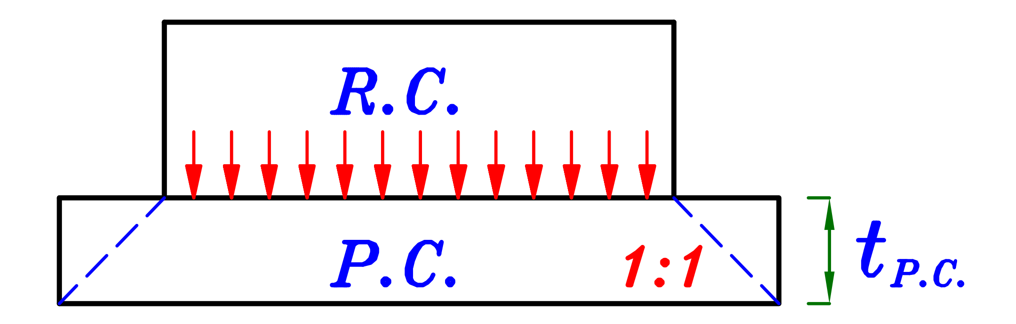
٢- وجود القاعده العاديه يحسن كثيرا من توزيع اجهاد القاعده من حمل الصمود على تربه التأسيس.

ملحوظه هامه :

تكون أبعاد القاعده العاديه $(L_{P.C.}, B_{P.C.})$ أكبر من أبعاد القاعده المسلحه $(L_{R.C.}, B_{R.C.})$ بمقدار (X) من كل جهه .

حيث المسافه (X) تمثل بروز القاعده العاديه عن المسلحه و تؤخذ بما يكفى لمنع حدوث إنهيار بالقص على هذا الجزء .

Diagonal tension Failure due to stress Concentration at P.C. Footing lower corner



Recommended $$X = t_{P.C.}$$

و بالتالى تكون العلاقه بين القاعدتين المسلحه و العاديه دائما كالاتى :-

$$L_{R.C.} = L_{P.C.} - 2\,t_{P.C.}$$

$$B_{R.C.} = B_{P.C.} - 2\,t_{P.C.}$$

Allowable stress of concrete.

(1) q_{scu} = Allowable **shear** stress in Foundations.

$$q_{scu} = 0.16 \sqrt{\frac{F_{cu}}{\gamma_c}} \quad (N/mm^2)$$

$$\gamma_c = 1.5$$

Calculate Actual Shear stress q_u = ✓

IF $q_u \leqslant q_{scu} \longrightarrow$ Safe Shear.

IF $q_u > q_{scu} \longrightarrow$ UnSafe Shear.

We have to increase depth of the Footing.

(2) q_{pcu} = Allowable punching shear stress in Foundations.

لحساب قيمه q_{pcu} و هى مقاومه الخرسانه للقص الناتج عن ثقب البلاطه.

نأخذ القيمه الاقل من الاربع قيم التاليه :-

$$q_{pcu} = 0.8\left(\frac{\alpha\, d}{b_o} + 0.2\right)\sqrt{\frac{F_{cu}}{\gamma_c}}$$

$\alpha = 4$ Interior Col.
$\alpha = 3$ Edge Col.
$\alpha = 2$ Corner Col.

b_o هو محيط الخرسانه التى سيحدث لها punching

$$q_{pcu} = 0.316\left(0.5 + \frac{a}{b}\right)\sqrt{\frac{F_{cu}}{\gamma_c}} \quad (N/mm^2)$$

a
b

a هو العرض الصغير للعمود

$$q_{pcu} = 0.316\sqrt{\frac{F_{cu}}{\gamma_c}} \quad (N/mm^2)$$

$$q_{pcu} = 1.60 \quad (N/mm^2)$$

Calculate Actual Shear stress q_{pu} = ✓

IF $q_{pu} \leq q_{pcu} \longrightarrow$ Safe Punching.

IF $q_{pu} > q_{pcu} \longrightarrow$ Unsafe Punching.

IF Unsafe Punching
We have to increase depth of the Footing.

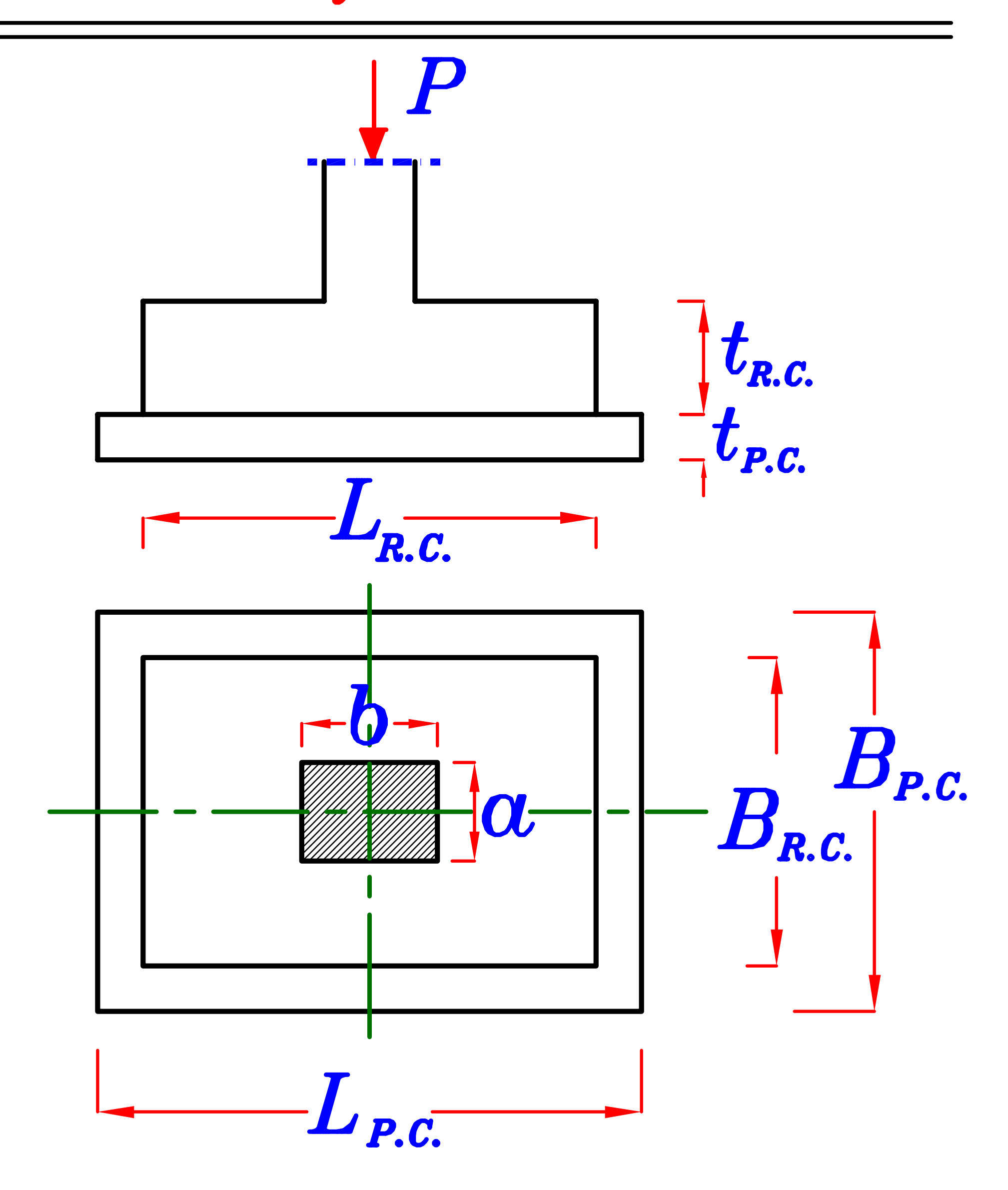
Requirements For design of shallow Foundations.

لتصميم أى قاعده لابد من توافر المعلومات الاتيه :

* Givens :-

1- Column load حمل العمود
2- Column dimensions أبعاد العمود
3- Allowable bearing capacity q_{all}
4- $t_{P.C.}$ can be assumed.
5- F_{cu} , F_y

* Concrete dimensions of shallow Foundations.



المبادئ الاساسيه لحسابات أبعاد أى قاعده .

① $t_{P.C.}$ is assumed $10 \rightarrow 40\ cm$

IF $t_{P.C.} = 10 \rightarrow 20\ cm$ --- فرشه نظافه و لا تؤخذ فى حسابات التصميم

IF $t_{P.C.} > 20 \rightarrow 40\ cm$ --- تعتبر قاعده عاديه و تؤخذ فى حسابات التصميم

② To calculate the area of the Footing.

Actual Stress on Soil = Allawable Stress of soil

$$F_{act} = \frac{P_{Col.\,(working)}\ (kN)}{Area\ of\ Footing\ (m^2)} = q_{all}\ (\text{Bearing Capacity of the soil})\ (kN/m^2)$$

where:

* $P_{Col.}$ (working) هو الحمل على العمود المراد عمل قاعده له و يكون (working) و يكون محسوب مسبقا من تصميم العمود من (load distribution)

* Area of Footing (m^2) أقل مساحه مطلوبه للقاعده

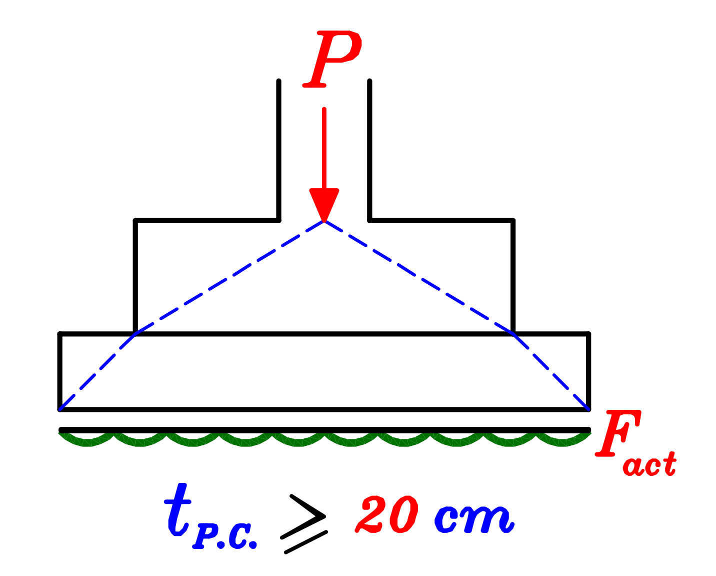
IF $t_{P.C.} \geq 20\ cm$ ---- و تكون مساحه القاعده العاديه

IF $t_{P.C.} < 20\ cm$ ---- و تكون مساحه القاعده المسلحه

* q_{all} (Bearing Capacity of the soil)

هو أكبر اجهاد تتحمله التربه (kN/m^2) و يتم تحديده من تقرير التربه .

$$Area\ of\ Footing\ (m^2) = \frac{P_{Col.\,(working)}\ (kN)}{q_{all}\ (kN/m^2)}$$

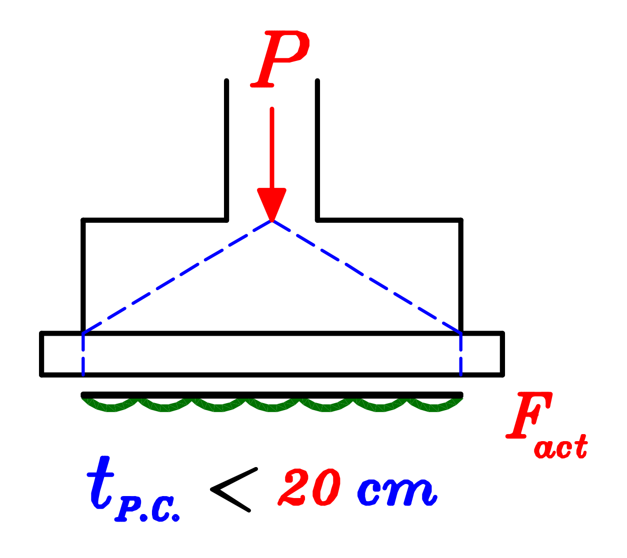


$t_{P.C.} \geq 20\ cm$

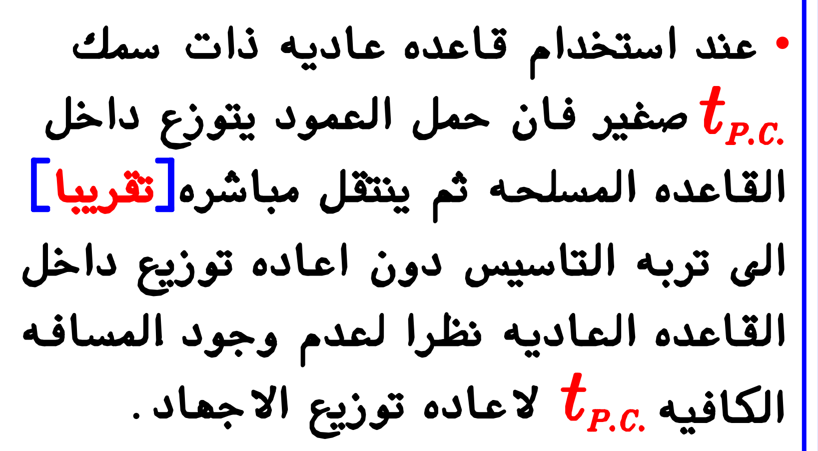
• عند استخدام قاعده عاديه ذات سمك $t_{P.C.}$ كبير فان حمل العمود يتوزع داخل القاعده المسلحه ثم يعاد توزيعه داخل القاعده العاديه نظرا لوجود المسافه الكافيه $t_{P.C.}$ لتوزيع الاجهاد للتربه .

$$\therefore\ F_{act} = \frac{P}{A_{P.C.}} = q_{all}$$

$$\therefore\ \boxed{A_{P.C.} = \frac{P}{q_{all}}}$$



$t_{P.C.} < 20\ cm$



• عند استخدام قاعده عاديه ذات سمك $t_{P.C.}$ صغير فان حمل العمود يتوزع داخل القاعده المسلحه ثم ينتقل مباشره[تقريبا] الى تربه التاسيس دون اعاده توزيع داخل القاعده العاديه نظرا لعدم وجود المسافه الكافيه $t_{P.C.}$ لاعاده توزيع الاجهاد .

$$\therefore\ F_{act} = \frac{P}{A_{R.C.}} = q_{all}$$

$$\therefore\ \boxed{A_{R.C.} = \frac{P}{q_{all}}}$$

* Minimum dimensions of R.C. Footing.

• يجب ألا تقل أبعاد و تسليح القواعد الخرسانيه المسلحه عن الاتى :-

• لا يقل عرض القاعده المسلحه عن 80 cm

$$\boxed{B_{R.C.\ minimum} = 80\ cm}$$

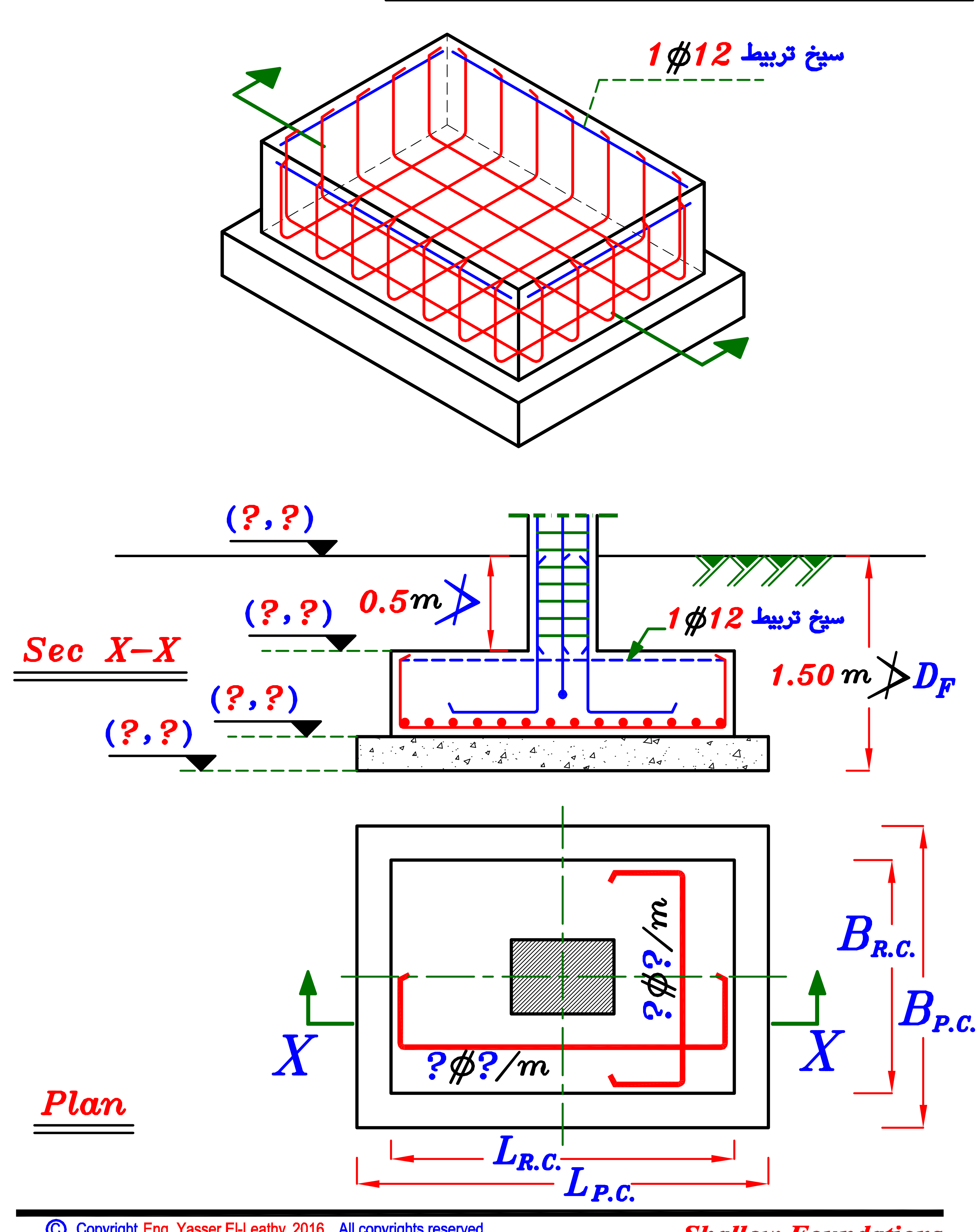
• لا يقل سُمك القاعده المسلحه عن 40 cm

$$\boxed{t_{R.C.\ minimum} = 40\ cm}$$

$$\boxed{d_{R.C.\ minimum} = 33\ cm}$$

Details of RFT. of shallow Foundation.

ملاحظات عامه على تفاصيل رسم القواعد [عامه لانواع القواعد]



• دائما حديد القواعد يكون سفلى فى الحالات الاتيه :-

• *Strip Footings*
• *Isolated Footings*

• يكون حديد القواعد سفلى+علوى فى الحالات الاتيه :-

• *Strip Footings*
• *Isolated Footings*

→ *in case of* $t_{R.C.} \geqslant 100\ cm$
حيث توضع شبكه علويه
$5 \phi 12 \backslash m'$

• *Combined Footings*
• *Strap beams*

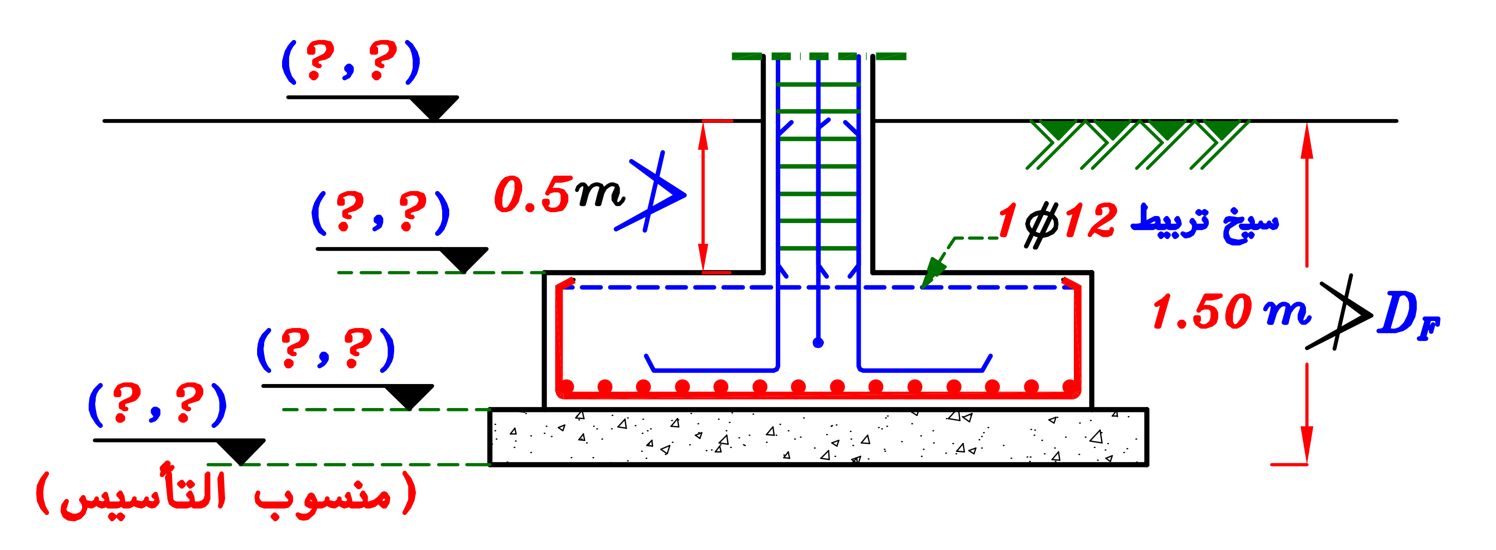
• يوضع سيخ تربيط $1 \phi 12$ عند أعلى الاسياخ فقط فى حاله القواعد المنفصله .

• أقل قطر سيخ يمكن استخدامه فى القواعد هو $\phi 12$
و أقل عدد للاسياخ فى المتر هو 5 و أكبر عدد هو 10

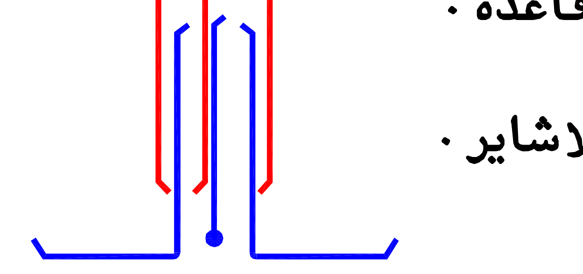
$A_{s_{min}}$

$$A_{s_{min}}\ (mm^2/m) = \left\{ \begin{array}{l} 1.5\,d\ (mm) \\ 5 \phi 12 \backslash m' \end{array} \right\} \text{الأكبر}$$

يجب مراعاه الاتى فى ال x-section



- يتم تهشير القاعده العاديه
- رسم حديد التسليح فى الاتجاهين و كتابه قيمه التسليح عليه



- يجب مراعه وضوح ال Cover = 7 cm = 70 mm
- يتم رسم حديد العمود و كيفيه اتصاله بالقاعده .
- يجب توضيح أماكن توقيف حديد العمود للاشاير .

- يتم كتابه المناسيب للاتى :

١- التربه .
٢- بدايه القاعده المسلحه .
٣- بدايه القاعده العاديه .
٤- نهايه القاعده العاديه (منسوب التأسيس) .

يجب مراعاه الاتى فى ال Plan

Plan

?ϕ?/m

?ϕ?/m

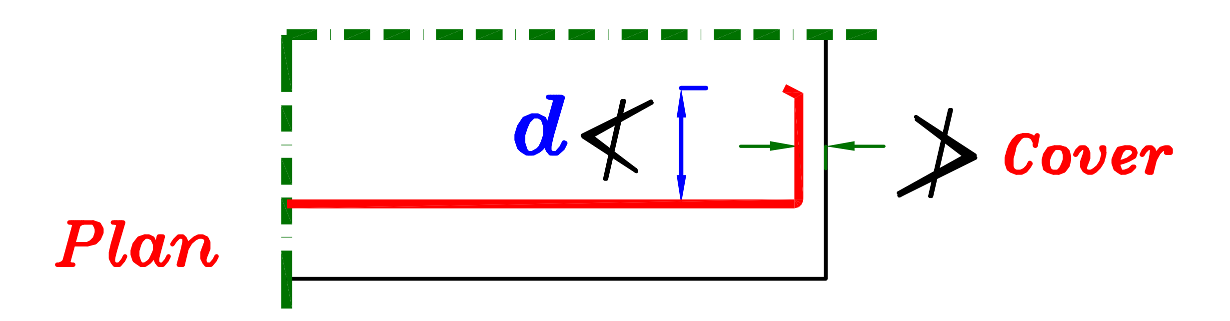
$B_{R.C.}$

$B_{P.C.}$

$L_{R.C.}$

$L_{P.C.}$

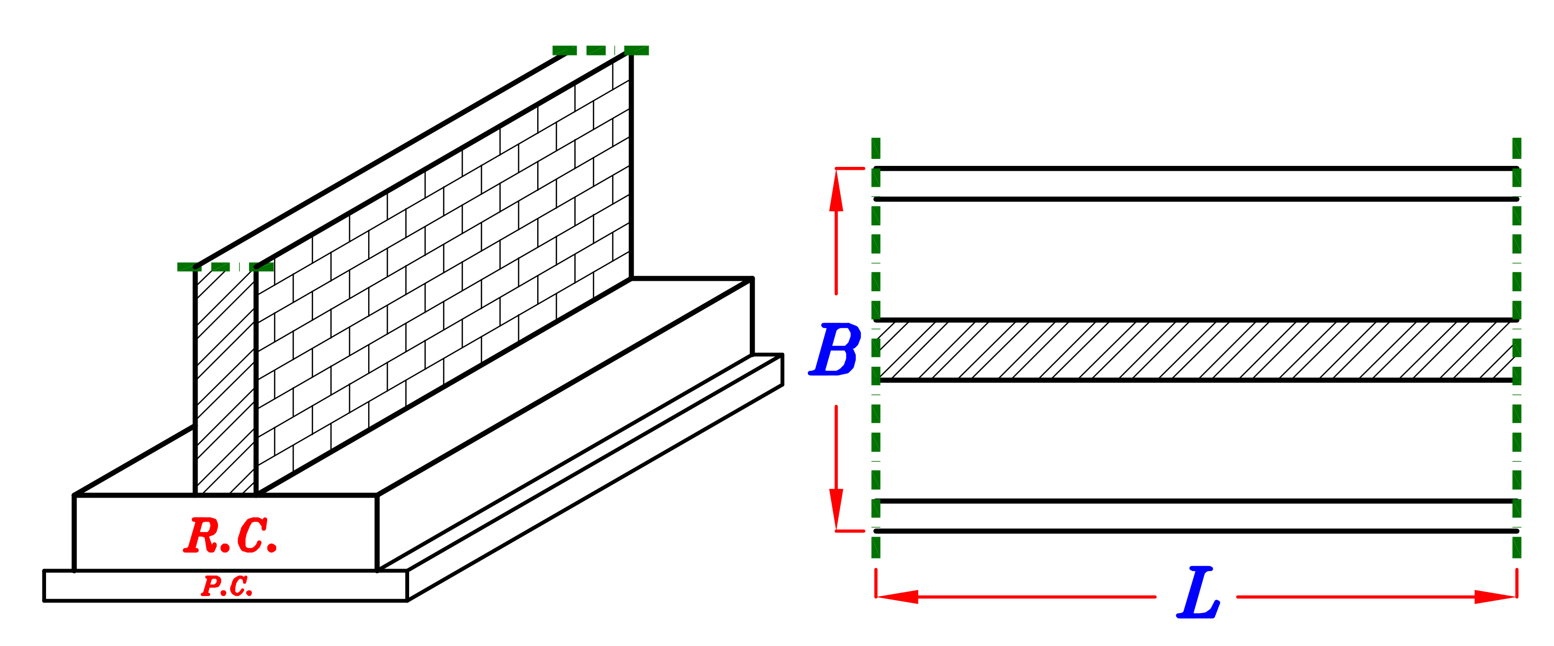
- رسم القاعده العاديه و المسلحه .
- رسم محاور العمود مع توقيع العمود بأبعاده و تهشير العمود .
- تفريد الحديد فى الاتجاهين مع مراعاه ال Cover و أن ركبه السيخ لا تزيد عن ال depth



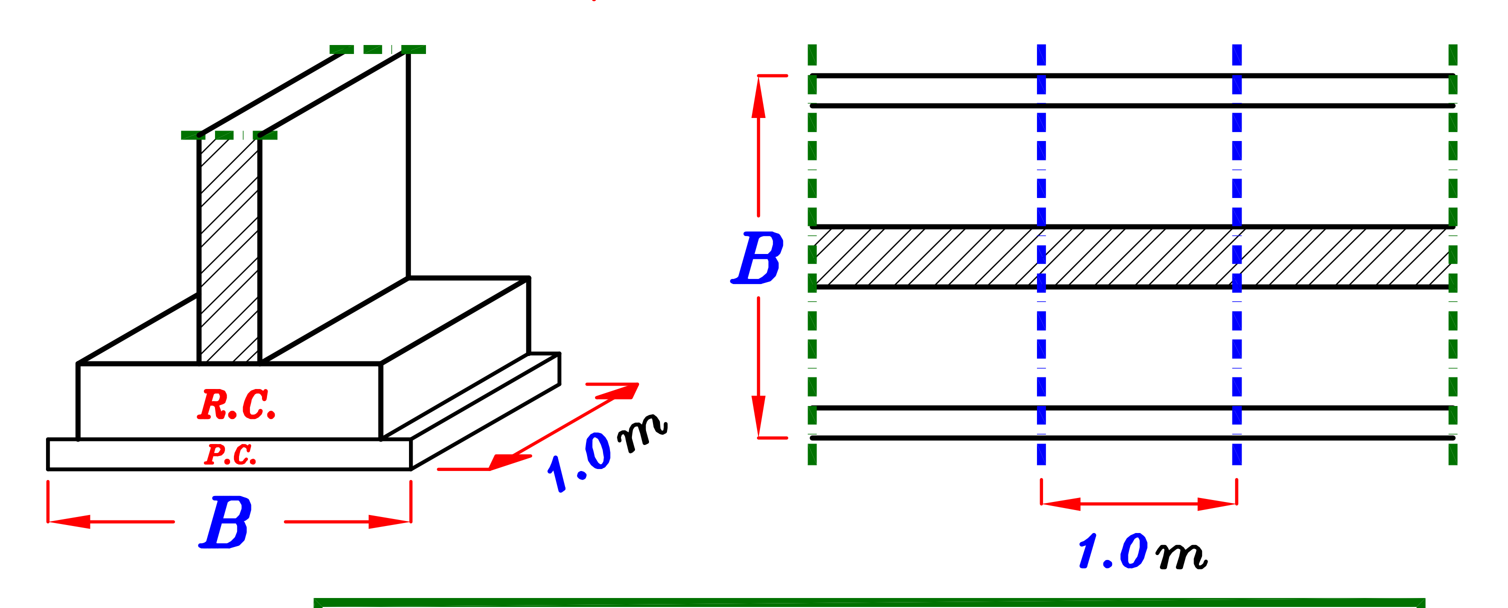
- كتابه قيم التسليح على الاسياخ ?ϕ?/m
- وضع أبعاد كامله لل R.C. Footing ، P.C. Footing ، Column

1 Design of strip Footings. تصميم القواعد الشريطيه .

هى قواعد طوليه لحمل الحوائط الساندة و الاسوار .

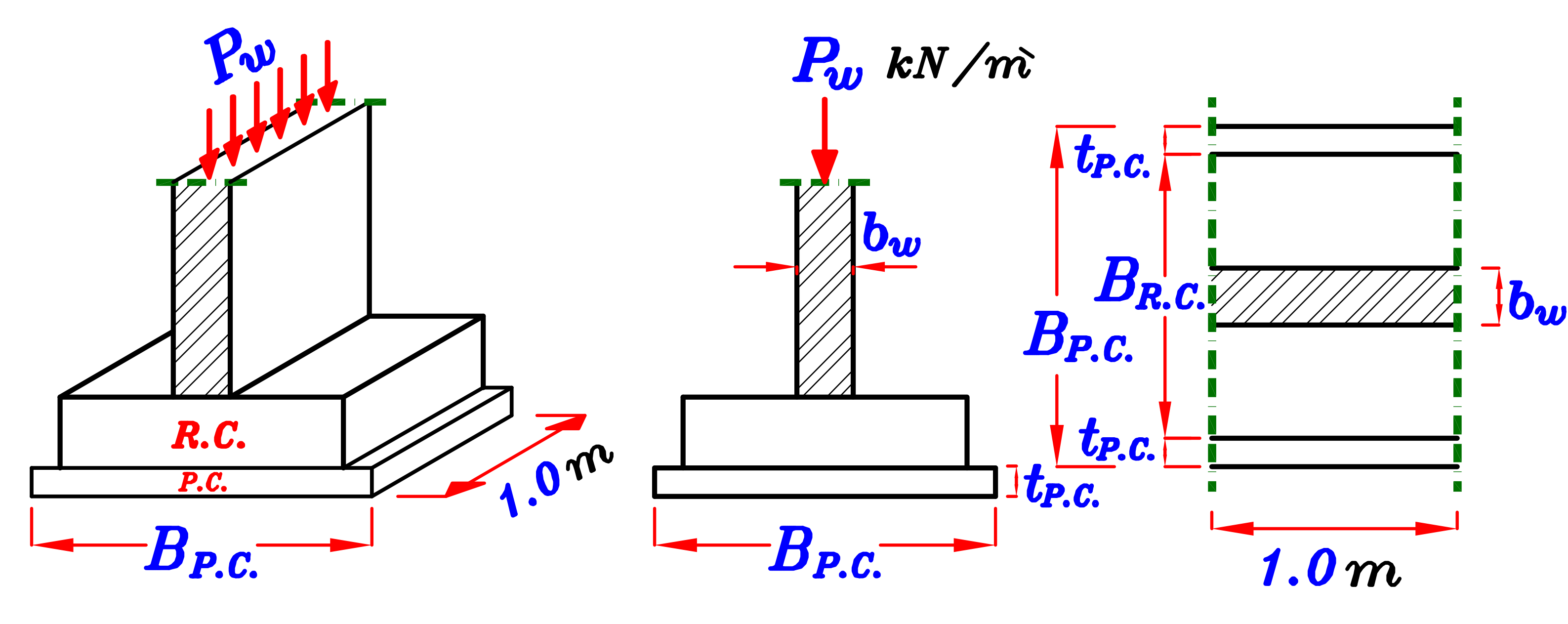


• فى هذه النوعيه من القواعد يكون الطول L كبيرا جدا بالنسبه للعرض B
لذلك نأخذ شريحه فى الاتجاه الطولى عرضها ١,٠ م و بقيه الطول بالمثل .



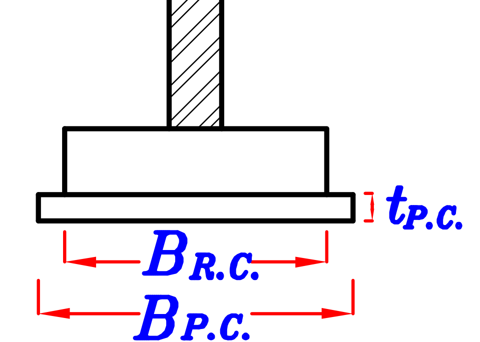
∴ نتعامل مع شريحه فى القاعده أبعادها $B * 1.0\ m$

* **Given :-**
  * Load of wall $= P_w = \checkmark\checkmark$ kN/m'
  * $q_{all} = \checkmark\checkmark$ kN/m²
  * $b_w = \checkmark\checkmark$ wall thickness
  * $t_{P.C.} = \checkmark\checkmark$



Steps of design.

1– Calculate the Footing area (Width of R.C. Footing.)



IF $t_{P.C.} \geq 20$ cm

$$A_{P.C.} = \frac{P_w}{q_{all}} = \checkmark\checkmark \ m^2 = B_{P.C.} * 1.0 \ m \text{ ----- get } B_{P.C.}$$

$$B_{P.C.} = \frac{P_w}{q_{all}}$$

$$B_{R.C.} = B_{P.C.} - 2\,t_{P.C.}$$

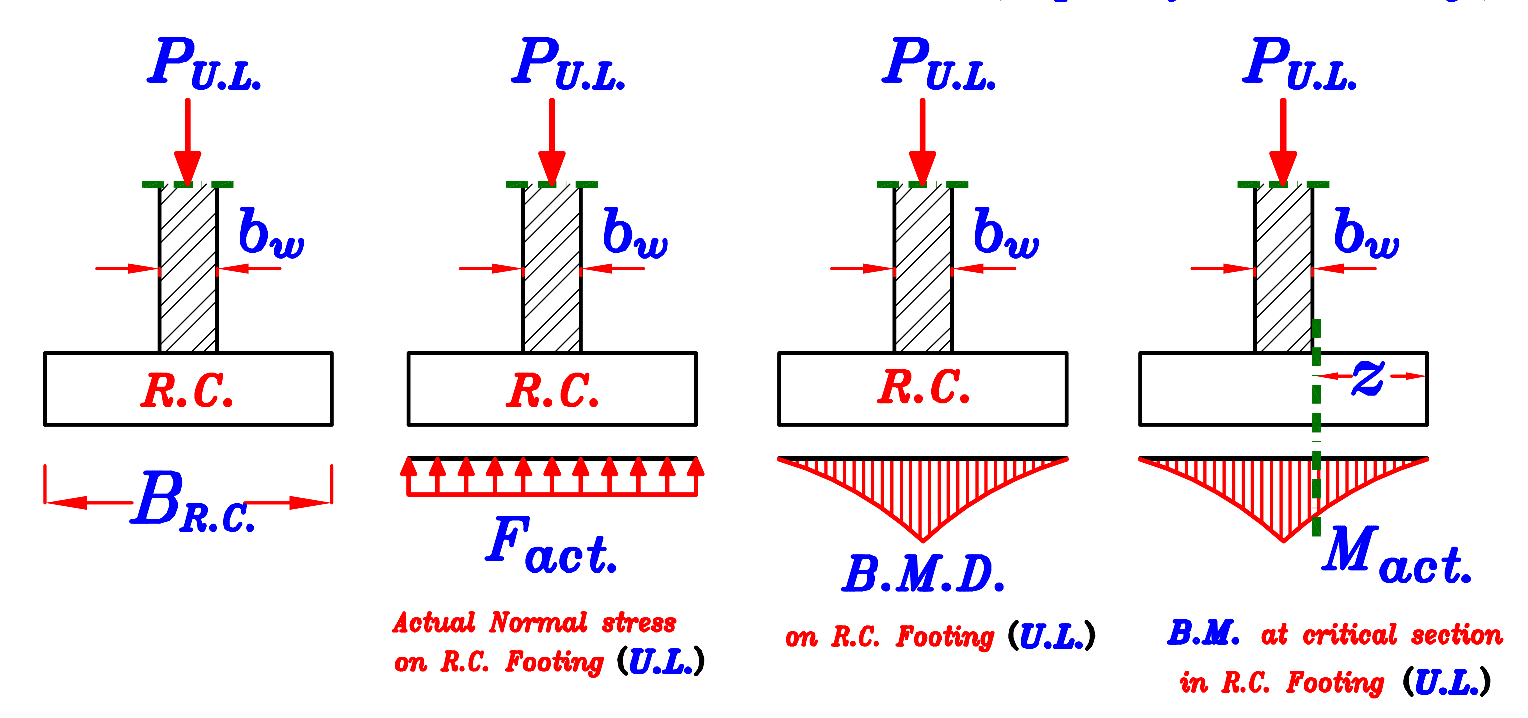
IF $t_{P.C.} < 20$ cm

$$A_{R.C.} = \frac{P_w}{q_{all}} = \checkmark\checkmark \ m^2 = B_{R.C.} * 1.0 \ m \text{ ----- get } B_{R.C.}$$

$$B_{R.C.} = \frac{P_w}{q_{all}}$$

$$B_{P.C.} = B_{R.C.} + 2\,t_{P.C.}$$

2- Design the critical sections For moment. (Depth of R.C. Footing.)



$B_{R.C.} = ✓✓\ m$

$$P_{U.L.} = P_w * 1.5 \quad (kN)$$

- Actual Normal stress on R.C. Footing (U.L.)

$$F_{act.} = \frac{P_{U.L.}}{B_{R.C.} * 1.0\ m} \quad (kN/m`)$$

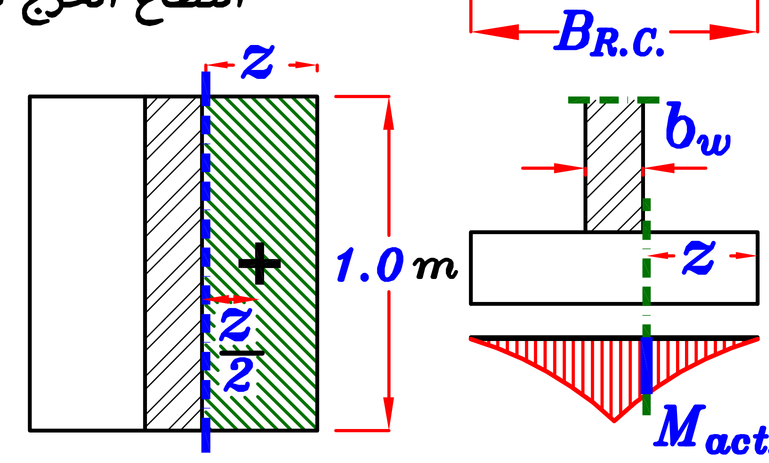
- Critical section of bending at R.C. Footing.

القطاع الحرج للعزوم يكون عند وش الحائط من أى جهه .

$$z = \frac{B_{R.C.} - b_w}{2} \quad (m)$$

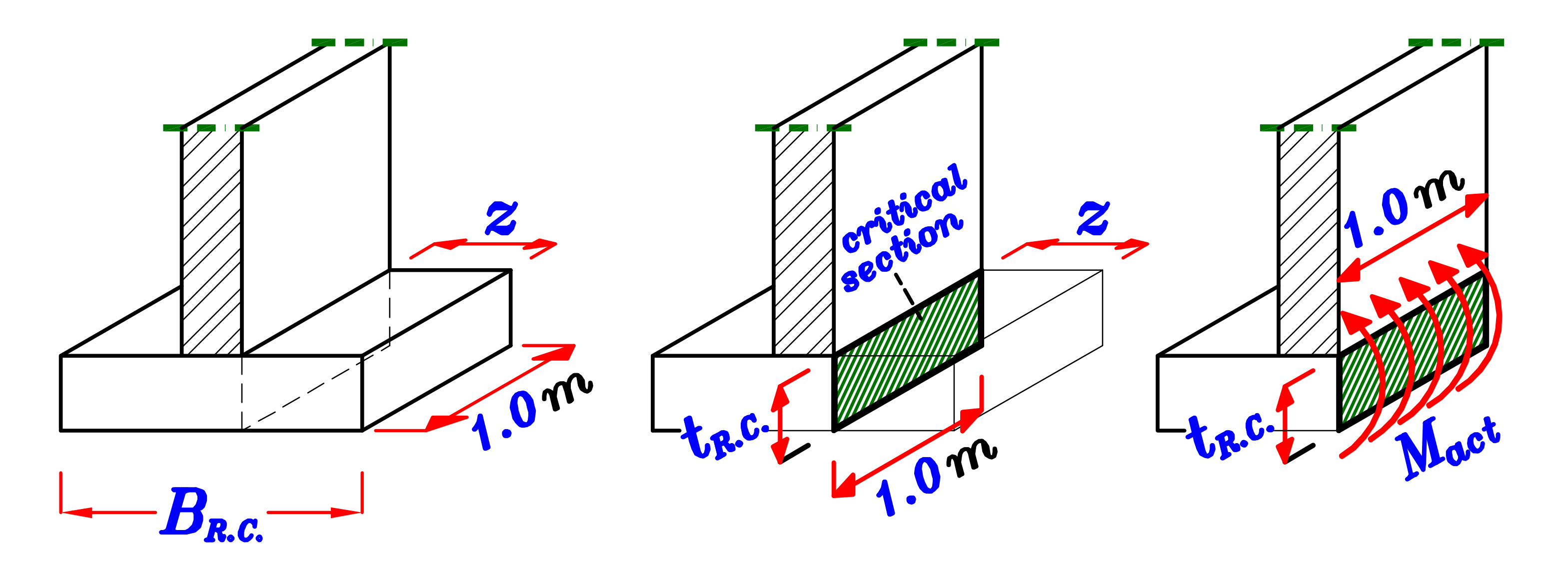
$Force = Stress * Area$

$Force = F_{act.} * z * 1.0\ m$



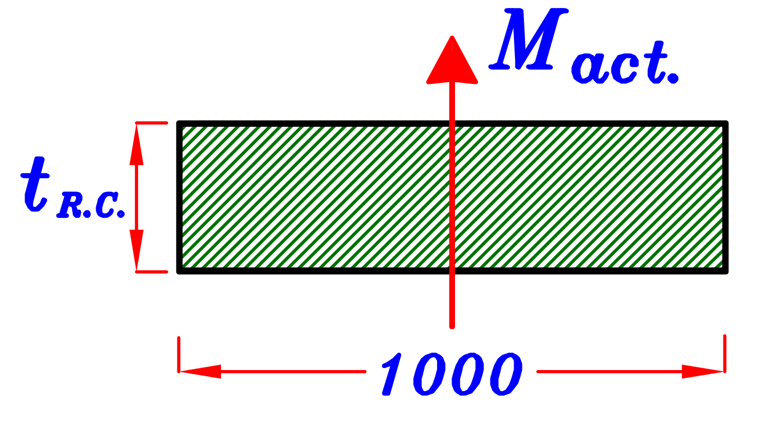
$Moment = Force * Distance$

$$M_{act.} = (F_{act.} * z * 1.0)\ \frac{z}{2} \quad (kN.m/m`)$$



Critical section

القطاع الذى سيتم تصميمه فى القاعده



$$d_{(mm)} = C_1 \sqrt{\frac{M_{act.}\,(kN.m) * 10^6}{F_{cu}\,(N/mm^2) * 1000\ (mm)}}$$

Choose $C_1 = (3.5 \rightarrow 5.0)$

Get $d = \checkmark\checkmark$ (mm)

يفضل فى القواعد أن نختار قيمه كبيره لـ C_1
حتى تكون تخانه القاعده كبيره
لضمان أن تكون القاعده **Rigid**

Take cover = 70 mm

يفضل أن يكون الـ cover فى القواعد كبير
لحمايه الحديد من الصداء .

$$t_{R.C.} = d + cover\ (70\ mm)$$

تقرب لاقرب ٥٠ مم بالزياده

$t_{R.C.\ minimum} = 400$ mm

$d_{R.C.\ minimum} = 330$ mm

3 – Check Shear.

Critical section of shear at R.C. Footing.

حمل الحائط يتوزع من أعلى الى أسفل داخل القاعده بميل $(1:1)$ و يكون الحساب عند $C.L.$ القاعده

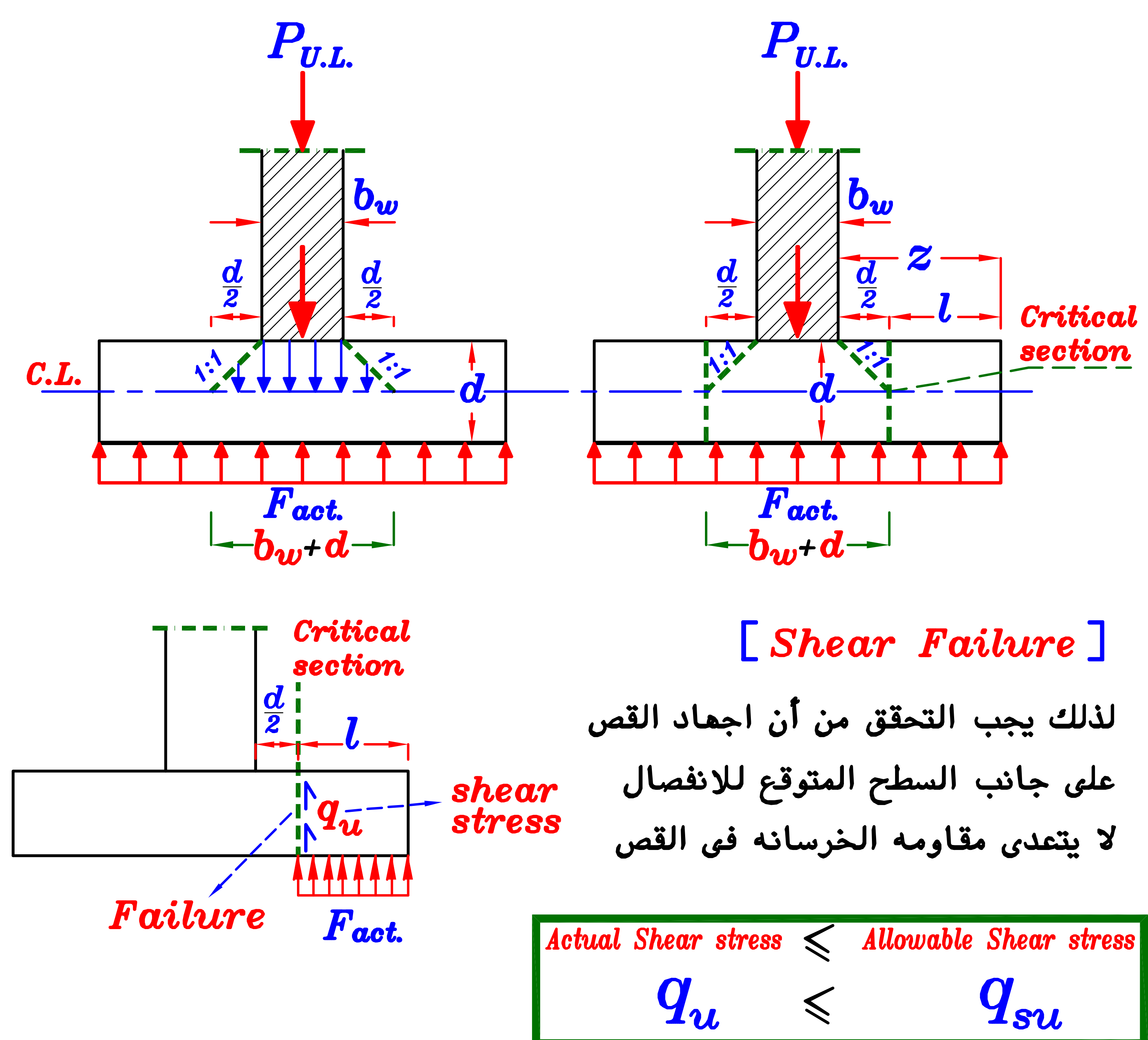
أى يكون على بعد $\left(\frac{d}{2}\right)$ من وش الحائط . أى يكون تأثيره على القاعده على عرض $(b_w + d)$

فتكون المنطقه فى منتصف القاعده $(b_w + d)$ عليها أقل اجهادات قص

حيث تكون قيمته تساوى رد فعل التربه على القاعده $F_{act.}$ مطروحا منه حمل الحائط $P_{U.L.}$

فيكون القطاع الحرج الذى عليه أكبر اجهادات قص على بعد $\left(\frac{d}{2}\right)$ من وش الحائط من أى جهه

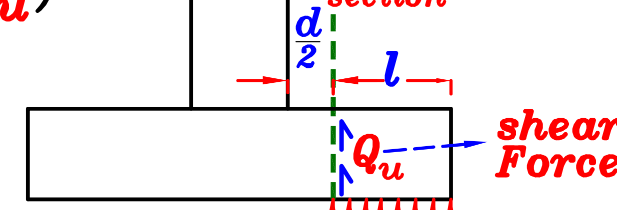
لانه أول قطاع عليه رد فعل الارض فقط و بالتالى يكون عليه أكبر Shear stress .



* Calculate $l = z - \frac{d}{2}$ (m)

* Calculate Actual shear Force. (Q_u)

$$Q_u = F_{act.} * l * 1.0\ m$$ (kN)



* Calculate Actual shear stress. (q_u)

$$q_u = \frac{Q_u}{b * d} = \frac{Q_{u\,(kN)} * 10^3}{1000 * d_{\,(mm)}}$$ (N/mm^2)

* Calculate Allowable shear stress. (q_{su})

$$q_{su} = 0.16 \sqrt{\frac{F_{cu}}{\gamma_c}}$$ (N/mm^2)

لاحظ أنه فى القواعد نعتمد فقط على مقاومه الخرسانه فى القص لانه لا توجد كانات حيث يصعب تشكيلها بالابعاد الضخمه للقواعد .

* Compare between

Actual shear stress (q_u) & Allowable shear stress (q_{su})

* IF $q_u \leqslant q_{su}$ $\longrightarrow$ Safe shear stresses
  No need to increase dimensions.

* IF $q_u > q_{su}$ $\longrightarrow$ Unsafe shear stresses
  We have to increase dimensions.

IF Unsafe shear stresses increase $t_{R.C.}$ by 100 mm

then Calculate:

$$d = t - 70 \text{ mm}$$

$$l = z - \frac{d}{2} \quad (m)$$

$$Q_u = F_{act.} * l * 1.0 \text{ m} \quad (kN)$$

$$q_u = \frac{Q_{u(kN)} * 10^3}{1000 * d_{(mm)}} \quad (N/mm^2)$$

then Recheck:

Actual shear stress (q_u) & Allowable shear stress (q_{su})

4- Reinforcement of the Footing.

From Step ② We Choose $C_1 = (3.5 \rightarrow 5.0)$

From $C_1 \xrightarrow{Get} J$

Get $$A_s = \frac{M_{act.}}{J\, F_y\, d} \quad (mm^2)$$

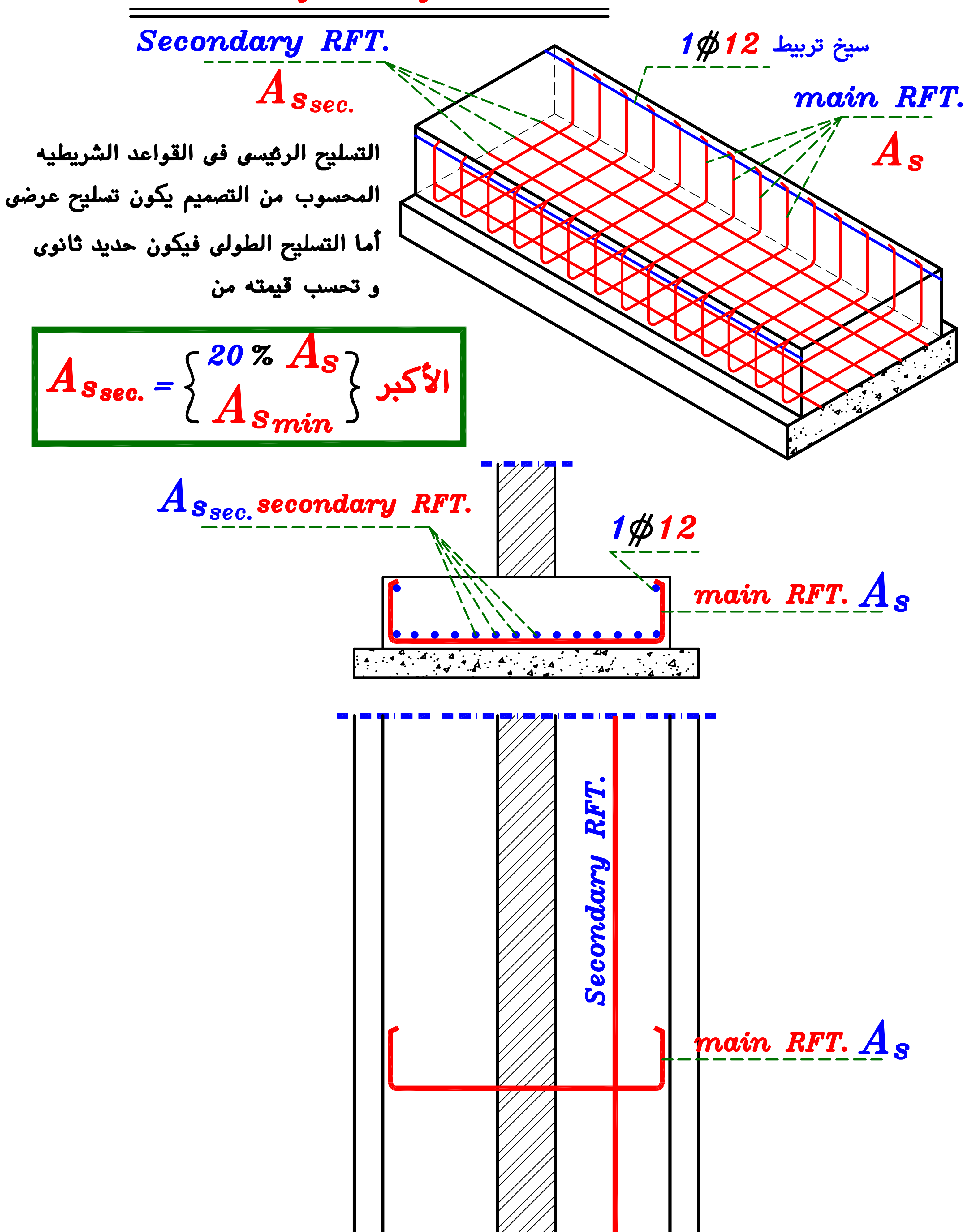
Check $A_{s_{min}}$

$$A_{s_{min}} \ (mm^2/m) = \begin{cases} 1.5\, d \ (mm) \\ 5 \phi 12/m' \end{cases}$$ الأكبر

IF $A_s \geqslant A_{s_{min}} \longrightarrow$ o.k.

IF $A_s < A_{s_{min}} \longrightarrow$ Take $A_s = A_{s_{min}}$

5- Details of Reinforcement.



التسليح الرئيسى فى القواعد الشريطيه
المحسوب من التصميم يكون تسليح عرضى
أما التسليح الطولى فيكون حديد ثانوى
و تحسب قيمته من

$$A_{s\,sec.} = \begin{Bmatrix} 20\,\%\ A_s \\ A_{s\,min} \end{Bmatrix} \text{ الأكبر}$$

Example.

It is required to design a strip Footing to Support a R.C retaining wall of thickness 25 cm. The wall working load is 350 kN/m`, and the allowable net bearing capacity in the Footing site is 100 kN/m^2. (F_{cu} = 25 N/mm^2, F_y = 360 N/mm^2). and draw details of RFT. to scale 1:50

Solution.

Data given.

Wall of thickness = 250 mm

P_{wall} (working) = 350 kN/m`    $P_{wall}$ (U.L.) = 350 * 1.5 = 525 kN/m`

Bearing capacity of the soil = q_{all} = 100 kN/m^2

F_{cu} = 25 N/mm^2 F_y = 360 N/mm^2

1- Calculate the Footing area (Width of R.C. Footing.)

Choose $t_{P.C.} = 30\ cm > 20\ cm$

$$B_{P.C.} = \frac{P_w}{q_{all}} = \frac{350\ (kN)}{100\ (kN/m^2)} = 3.50\ m$$

$$B_{R.C.} = B_{P.C.} - 2\,t_{P.C.} = 3.50 - 2 * 0.3 = 2.90\ m$$

$B_{P.C.} = 3.50\ m$ $B_{R.C.} = 2.90\ m$

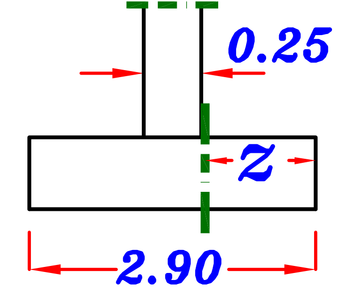
2- Design the critical sections For moment. (Depth of R.C. Footing.)

- Actual Normal stress on R.C. Footing (U.L.)

$$F_{act.} = \frac{P_{U.L.}}{B_{R.C.} * 1.0\ m} = \frac{525}{2.90 * 1.0} = 181.03 \ kN/m'$$

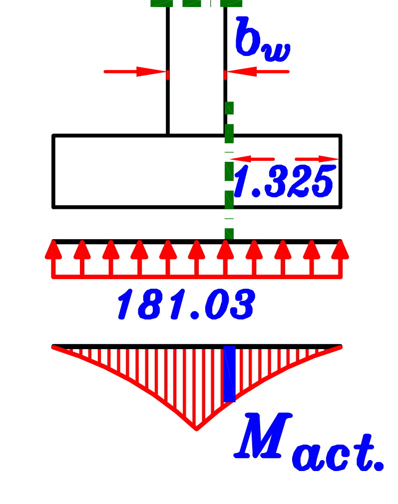
- Critical section of bending at R.C. Footing.

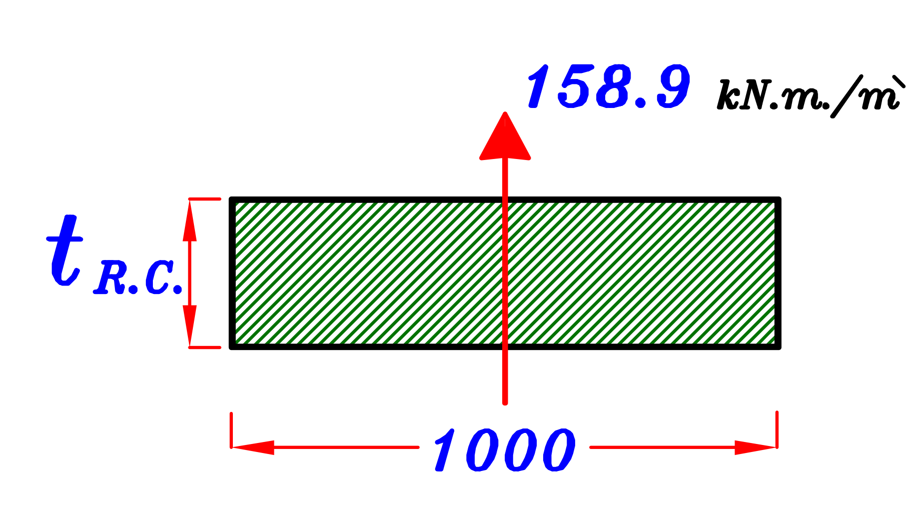
$$Z = \frac{B_{R.C.} - b_w}{2} = \frac{2.90 - 0.25}{2} = 1.325 \ m$$

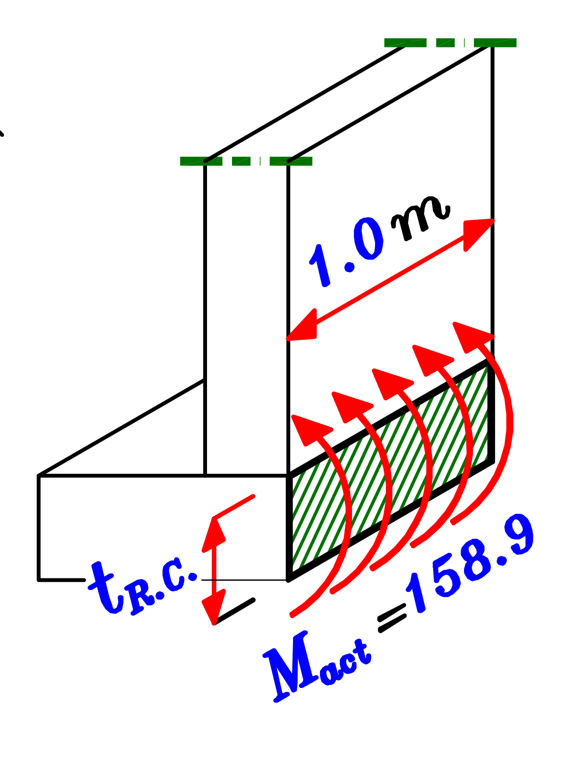


$$M_{act.} = \frac{F_{act.} * Z^2}{2} * 1.0\ m$$

$$M_{act.} = \frac{181.03 * 1.325^2}{2} = 158.9 \ kN.m./m'$$







$$\because\ d = C_1 \sqrt{\frac{M_{act.}}{F_{cu} * b}}$$

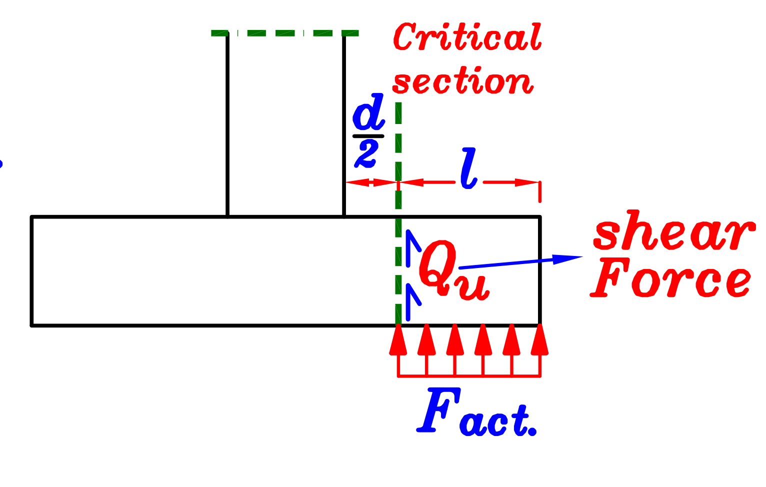
Choose $C_1 = 5.0$

$$\therefore\ d = 5.0 \sqrt{\frac{158.9 * 10^6}{25 * 1000}} = 398.6\ mm$$

$$t_{R.C.} = d + 70\ mm = 398.6 + 70 = 468.6\ mm$$

$t_{R.C.} = 500\ mm$ **$d = 430\ mm$**

3- Check Shear.



* **Critical section For Shear.**

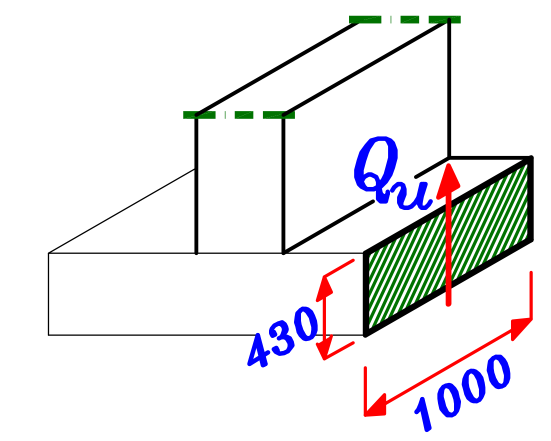
$$l = z - \frac{d}{2}$$

$$l = 1.325 - \frac{0.43}{2} = 1.11\ m$$

* **Actual shear Force. (Q_u)**

$$Q_u = F_{act.} * l * 1.0\ m = 181.03 * 1.11 * 1.0 = 200.94\ kN$$

* **Actual shear stress. (q_u)**



$$q_u = \frac{Q_u}{b * d} = \frac{200.94 * 10^3}{1000 * 430} = 0.467\ N/mm^2$$

* **Allowable shear stress. (q_{su})**

$$q_{su} = 0.16 \sqrt{\frac{F_{cu}}{\gamma_c}} = 0.16 \sqrt{\frac{25}{1.5}} = 0.653\ N/mm^2$$

$q_u < q_{su}$ ⟶ Safe shear stresses
No need to increase dimensions.

4- Reinforcement of the Footing.

From $C_1 = 5.0 \longrightarrow J = 0.826$

$$A_s = \frac{M_{act.}}{J\,F_y\,d} = \frac{158.9 * 10^6}{0.826 * 360 * 430} = 1242.7\ mm^2$$

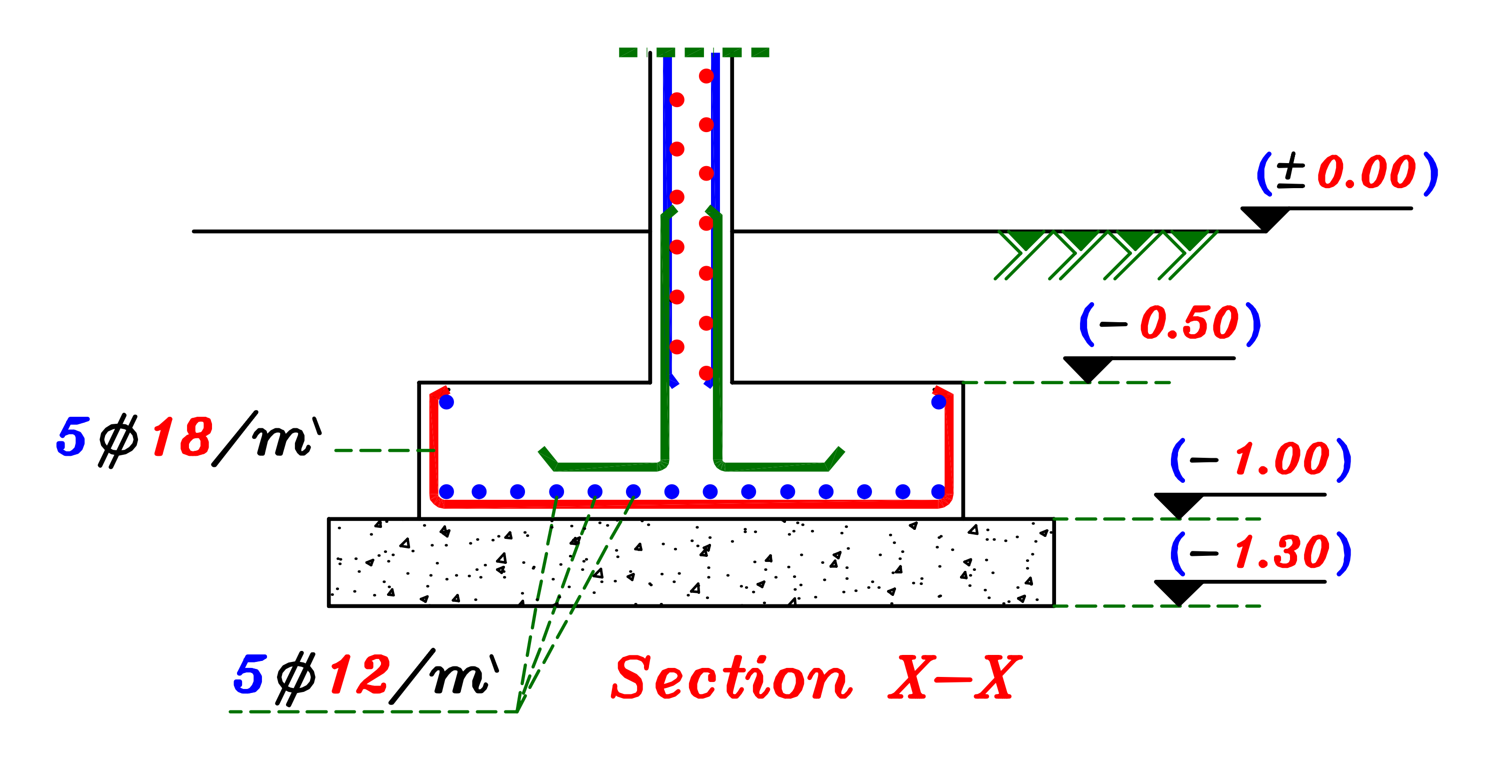
Check $A_{s_{min}}$

$$A_{s_{min}} = \left\{ \begin{array}{l} 1.5\,d = 1.5 * 430 = 645 \\ 5\phi 12/m' = 565 \end{array} \right\} 645\ mm^2$$

$\therefore\ A_s > A_{s_{min}} \longrightarrow$ o.k.

$A_s = 1242.7\ mm^2$ **$5\phi 18/m'$**

5- Details of Reinforcement. scale 1:50



0.30 2.90 0.30

X X

5ϕ12/m'

5ϕ18/m'

Plan

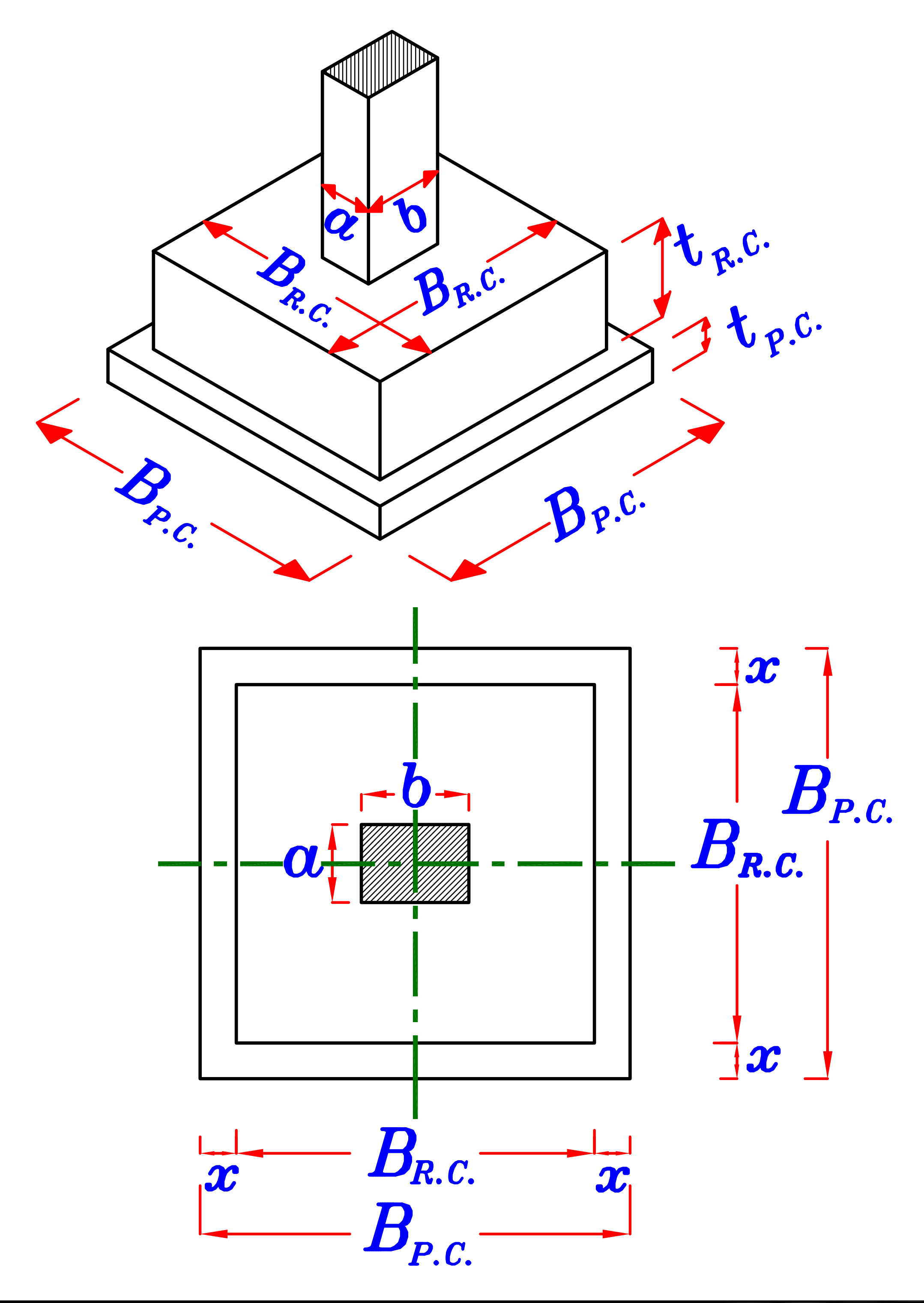
Isolated Footings. القواعد المنفصله

* هى القواعد التى يرتكز عليها عمود واحد فقط و تكون اما مربع أو مستطيل و يكون العمود مربع أو مستطيل أو دائرى .

* يمكن للقاعده المربعه أن تحمل عمود مستطيل أو مربع و بالمثل القاعده المستطيله .

2 Design of Isolated Square Footings.

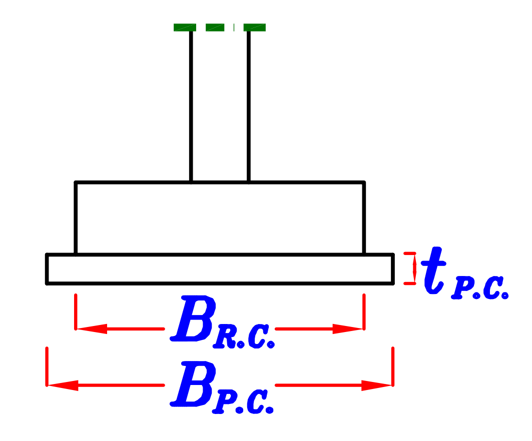
تصميم القواعد المنفصله المربعه .



Steps of design.

* **Given.**
  * Load of column = P_w = ✓✓ kN
  * Bearing capacity of soil = q_{all} = ✓✓ kN/m^2
  * Dimensions of the column. $(a * b)$ مستطيل أو مربع
  * $t_{P.C.}$ = ✓✓

1– Calculate the Footing area. (Width of R.C. Footing.)



IF $t_{P.C.} \geqslant 20$ cm

get $B_{P.C.}$ From

$$A_{P.C.} = \frac{P_w}{q_{all}} = ✓✓ \ m^2 = B_{P.C.} * B_{P.C.}$$

$$B_{P.C.} = \sqrt{\frac{P_w}{q_{all}}}$$

$$B_{R.C.} = B_{P.C.} - 2\,t_{P.C.}$$

IF $t_{P.C.} < 20$ cm

get $B_{R.C.}$ From

$$A_{R.C.} = \frac{P_w}{q_{all}} = ✓✓ \ m^2 = B_{R.C.} * B_{R.C.}$$

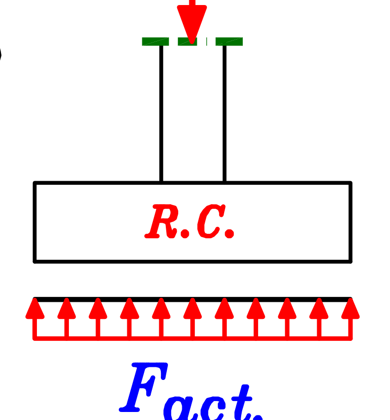
$$B_{R.C.} = \sqrt{\frac{P_w}{q_{all}}}$$

$$B_{P.C.} = B_{R.C.} + 2\,t_{P.C.}$$

2- Design the critical sections For moment. (Depth of R.C. Footing)

$B_{R.C.} = \checkmark\checkmark\ m$

$$P_{U.L.} = P_w * 1.5 \quad (kN)$$



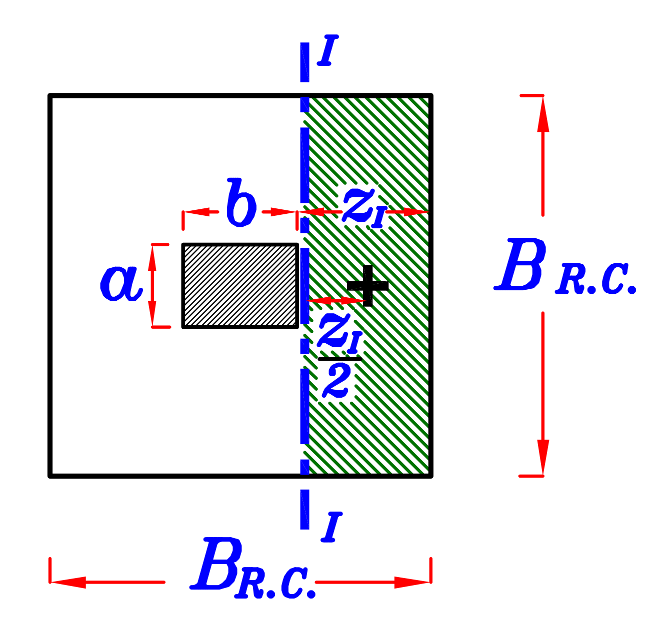
- Actual Normal stress on R.C. Footing (U.L.)

$$F_{act.} = \frac{P_{U.L.}}{B_{R.C.} * B_{R.C.}} \quad (kN/m)$$

- Critical section of bending at R.C. Footing.

ناخذ القطاعات الحرجه للعزوم على وش العمود من الجهتين .

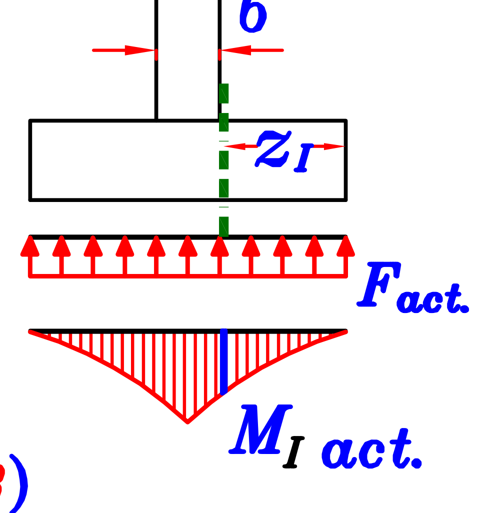
Direction I



$$Z_I = \frac{B_{R.C.} - b}{2} \quad (m)$$

Force = Stress * Area

$$Force = F_{act.} * Z_I * B_{R.C.}$$



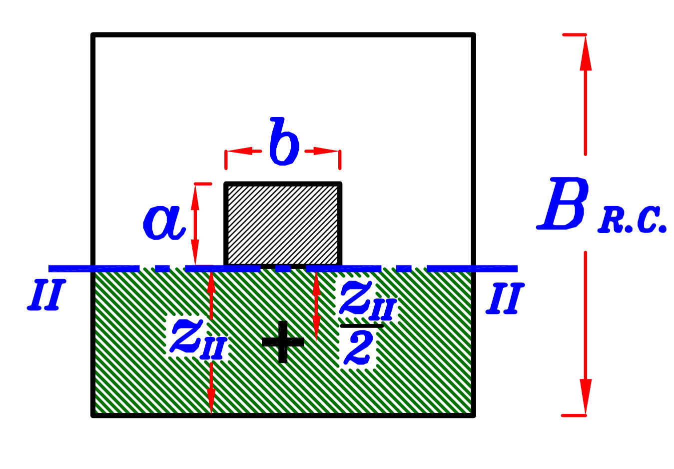
Moment = Force * Distance

$$M_{I\,act.} = (F_{act.} * Z_I * B_{R.C.}) \frac{Z_I}{2}$$

$(kN.m./B)$

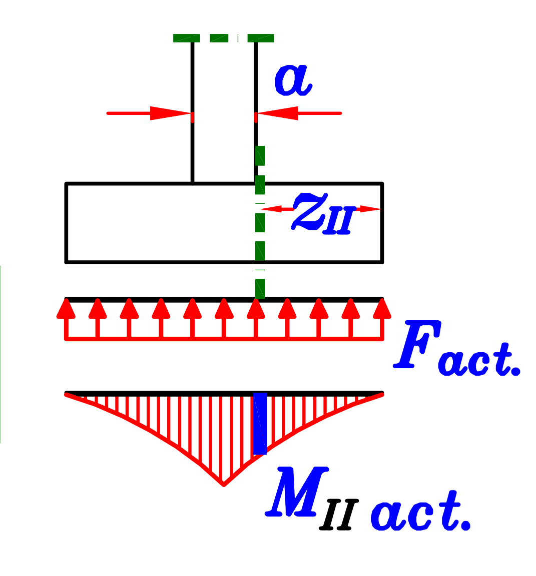
Direction II

$$Z_{II} = \frac{B_{R.C.} - a}{2} \quad (m)$$



$$Force = Stress * Area$$

$$Force = F_{act.} * Z_{II} * B_{R.C.}$$



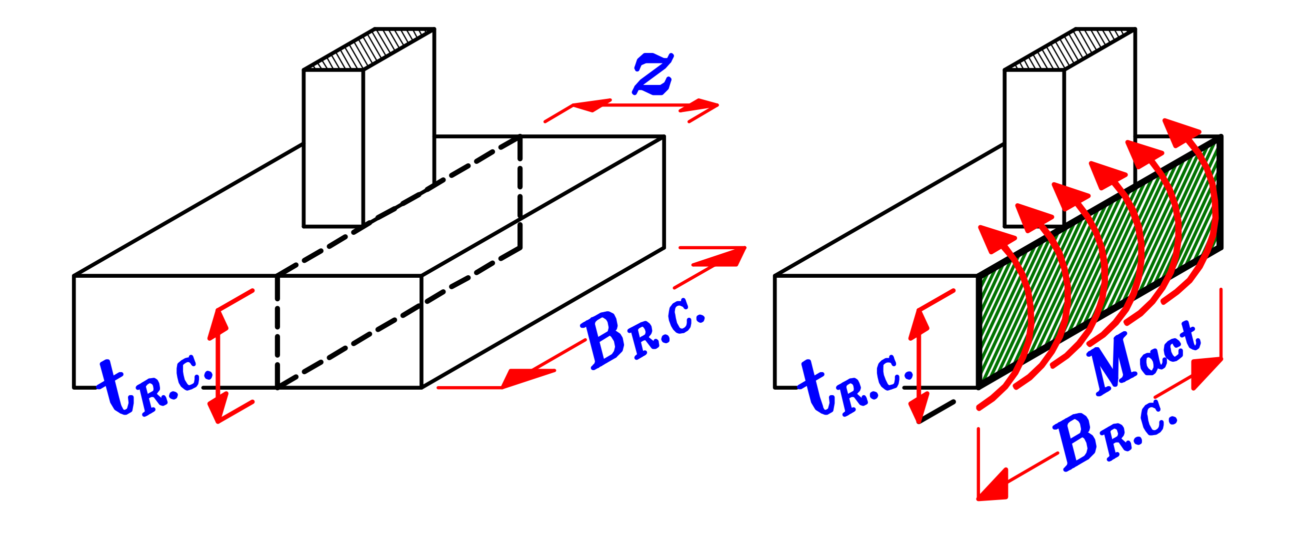
$$Moment = Force * Distance$$

$$M_{II\,act.} = (F_{act.} * Z_{II} * B_{R.C.}) \frac{Z_{II}}{2}$$

$(kN.m/B)$

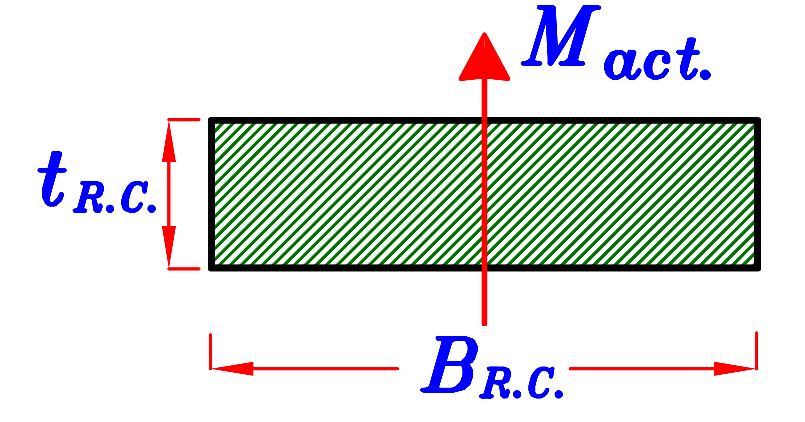
$M_{I\,act.}$ & $M_{II\,act.}$ يتم التصميم على العزم الاكبر من

$Z_I < Z_{II}$ لان $M_{I\,act.} < M_{II\,act.}$ ملحوظه



Critical section

القطاع الذى سيتم تصميمه فى القاعده



$$d_{(mm)} = C_1 \sqrt{\frac{M_{act.(kN.m)} * 10^6}{F_{cu}(N/mm^2) * B_{R.C.}(mm)}}$$

Choose $C_1 = (3.5 \rightarrow 5.0)$

يفضل فى القواعد أن نختار قيمه كبيره لـ C_1
حتى تكون تخانه القاعده كبيره
لضمان أن تكون القاعده **Rigid**

Get $d = \checkmark\checkmark$ (mm)

Take cover = 70 mm

يفضل أن يكون الـ cover فى القواعد كبير
لحمايه الحديد من الصداء .

$$t_{R.C.} = d + cover\ (70\ mm)$$

تقرب لاقرب ٥٠ مم بالزياده

$t_{R.C.\,minimum} = 400$ mm

$d_{R.C.\,minimum} = 330$ mm

3 – Check Shear.

Critical section of shear at R.C. Footing.

حمل العمود يتوزع من أعلى الى أسفل داخل القاعده بميل (1:1) و يكون الحساب عند C.L. القاعده

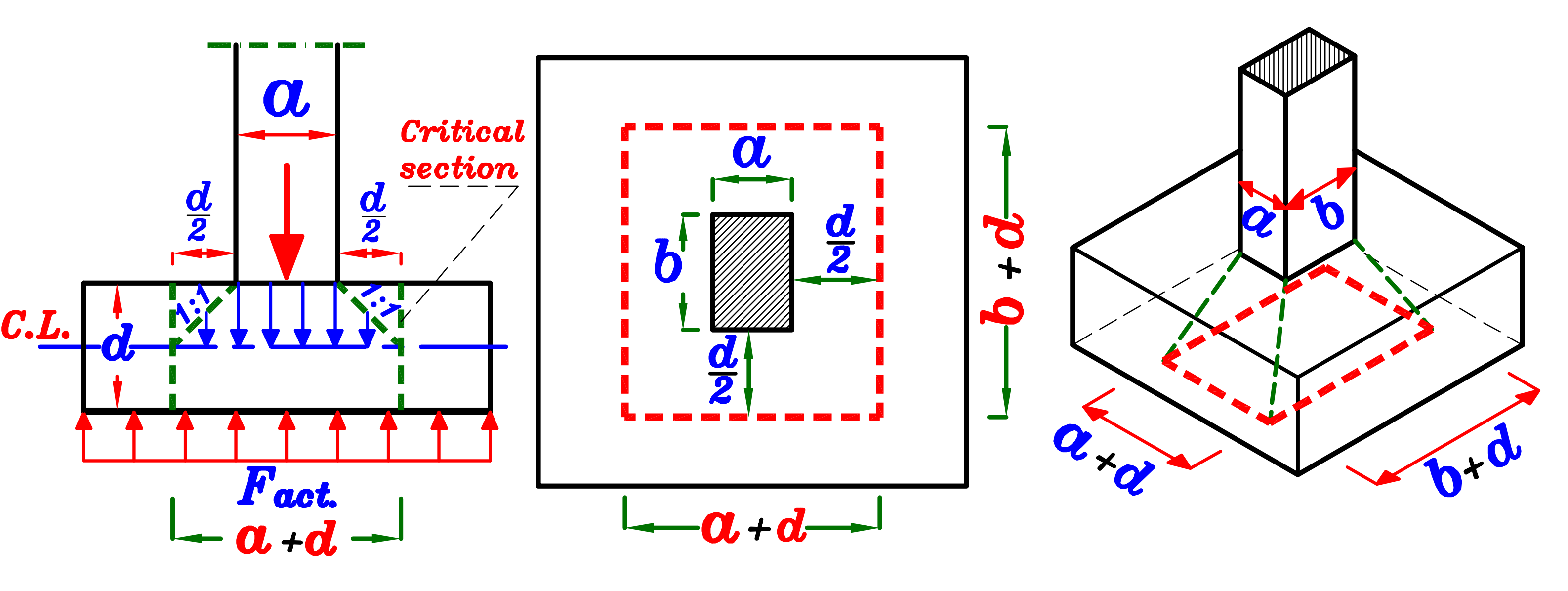
أى يكون تأثيره على القاعده على عرض $(b+d)$ & $(a+d)$

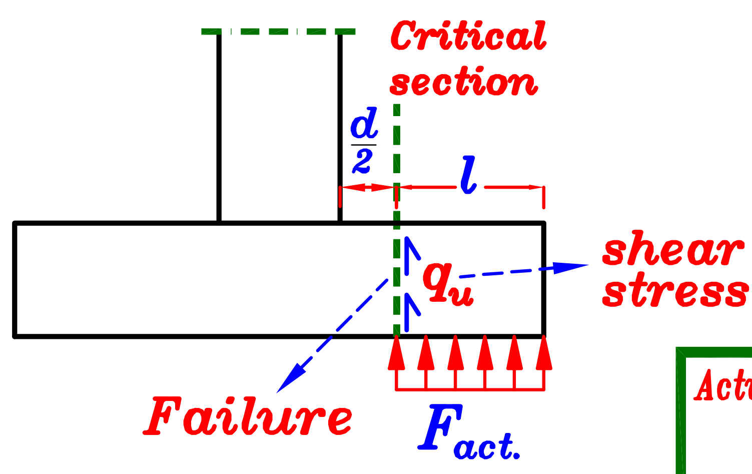
فتكون المساحه $(b+d) * (a+d)$ فى منتصف القاعده عليها أقل اجهادات قص

حيث تكون قيمته تساوى رد فعل التربه على القاعده $F_{act.}$ مطروحا منه حمل العمود $P_{U.L.}$

فيكون القطاع الحرج الذى عليه أكبر اجهادات قص على بعد $\left(\frac{d}{2}\right)$ من وش العمود من أى جهه

لانه أول قطاع عليه رد فعل الارض فقط و بالتالى يكون عليه أكبر Shear stress .





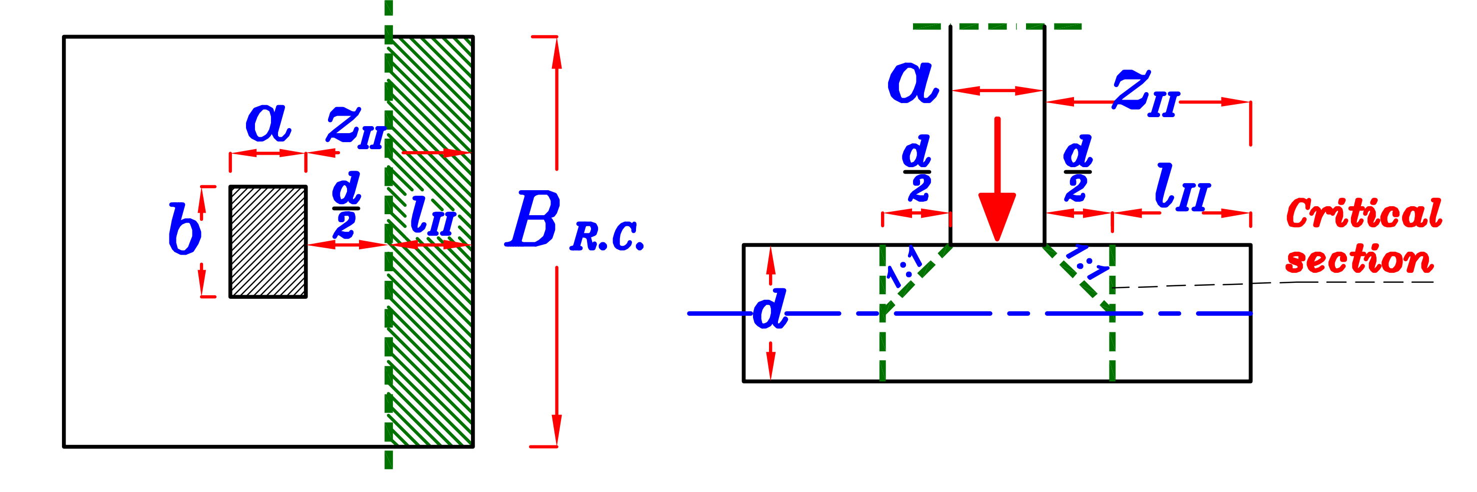
[Shear Failure]

لذلك يجب التحقق من أن اجهاد القص

على جانب السطح المتوقع للانفصال

لا يتعدى مقاومه الخرسانه فى القص

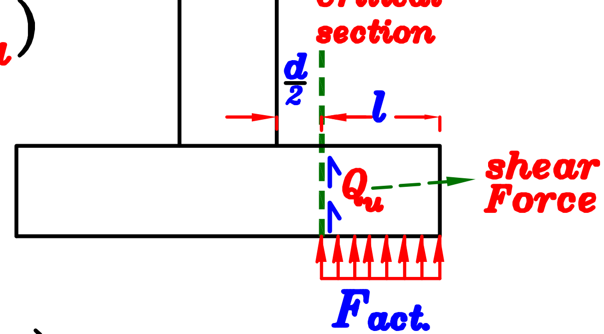
Actual Shear stress	≤	Allowable Shear stress
q_u	≤	q_{su}



* Calculate $$l_{II} = z_{II} - \frac{d}{2} \quad (m)$$

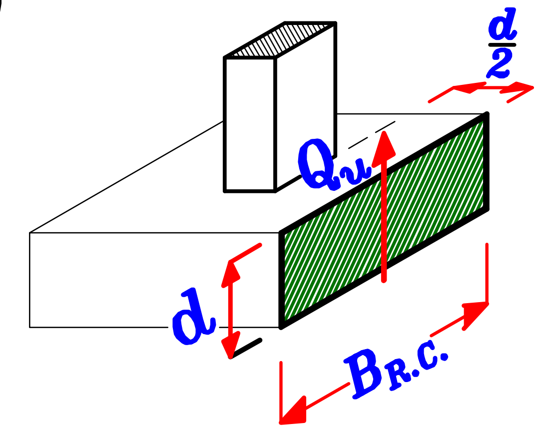
ملحوظه $l_I < l_{II}$ لان $z_I < z_{II}$

* Calculate Actual shear Force. (Q_u)



$$Q_u = F_{act.} * l_{II} * B_{R.C.} \quad (kN)$$

* Calculate Actual shear stress. (q_u)



$$q_u = \frac{Q_u}{b * d}$$

$$q_u = \frac{Q_u\,(kN) * 10^3}{B_{R.C.} * d\,(mm)} \quad (N/mm^2)$$

* Calculate Allowable shear stress. (q_{su})

$$q_{su} = 0.16\sqrt{\frac{F_{cu}}{\gamma_c}} \quad (N/mm^2)$$

لاحظ أنه فى القواعد نعتمد فقط
على مقاومه الخرسانه فى القص
لانه لا توجد كانات حيث يصعب
تشكيلها بالابعاد الضخمه للقواعد .

* Compare between

Actual shear stress (q_u) & Allowable shear stress (q_{su})

* IF $q_u \leqslant q_{su}$ $\longrightarrow$ Safe shear stresses
No need to increase dimensions.

* IF $q_u > q_{su}$ $\longrightarrow$ UnSafe shear stresses
We have to increase dimensions.

IF UnSafe shear stresses increase $t_{R.C.}$ by 100 mm

then Calculate:

$$d = t_{R.C.} - 70 \text{ mm}$$

$$l_{II} = z_{II} - d \quad (m)$$

$$Q_u = F_{act.} * l_{II} * B_{R.C.} \quad (kN)$$

$$q_u = \frac{Q_u (kN) * 10^3}{B_{R.C.} * d (mm)} \quad (N/mm^2)$$

then ReCheck:

Actual shear stress (q_u) & Allowable shear stress (q_{su})

4 – Check Punching Shear. القص الثاقب .

يجب التأكد من أن العمود لن يخترق القاعده .

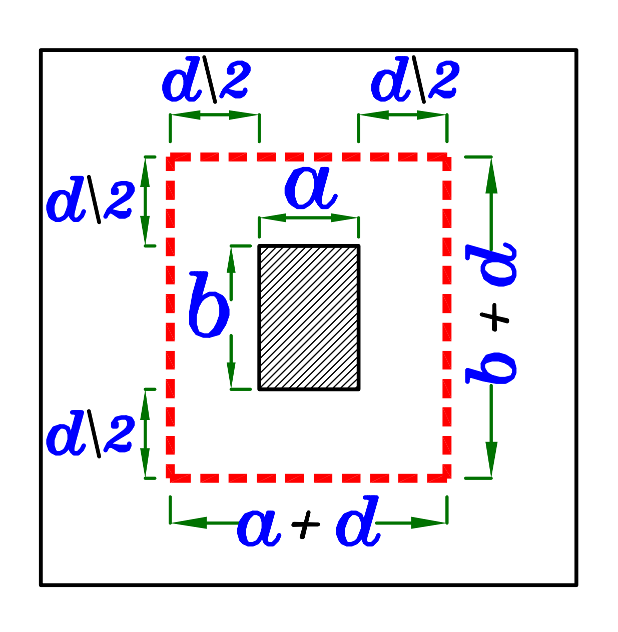
و للتأكد من ذلك نحسب q_{pu} و هو اجهاد القص الذى سينتج عن ثقب العمود للقاعده .

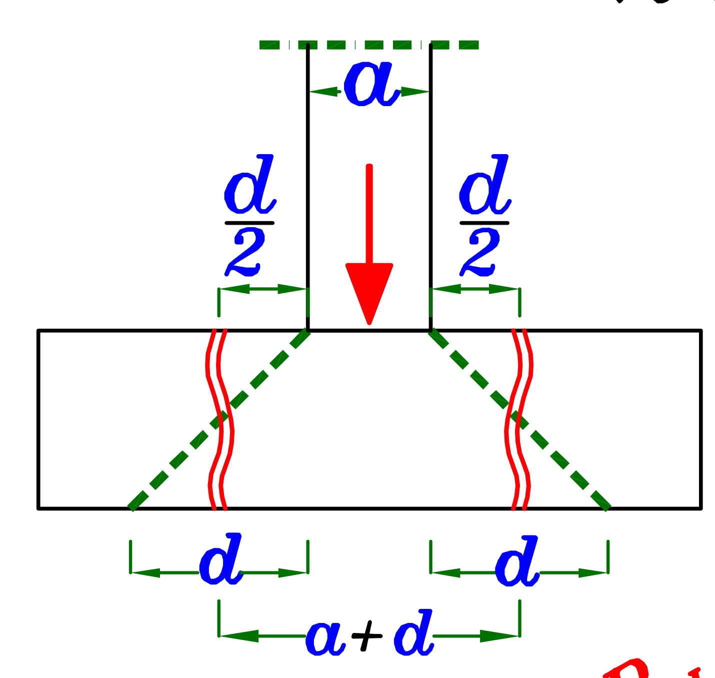
و نحسب q_{pcu} و هى مقاومه الخرسانه للقص الناتج عن ثقب القاعده .

The concrete area which resist punching shear.

تحديد مساحه الخرسانه المقاومه للقص الثاقب .

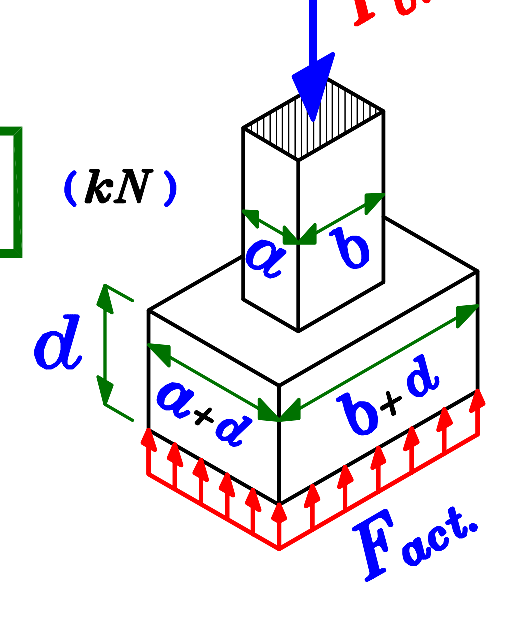
القطاع الحرج فى القص الثاقب عباره عن محيط يحيط بالعمود على مسافه $\frac{d}{2}$ من وش العمود من كل جهه .



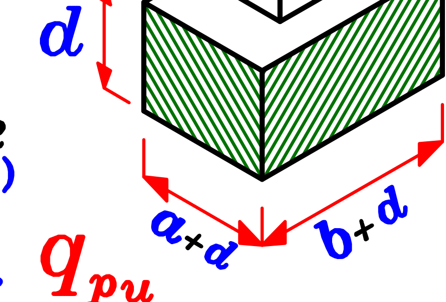


* Calculate Punching Force. (Q_p)

$$Q_p = P_{U.L.} - (F_{act.}) \left[(a+d)(b+d) \right] \quad (kN)$$



* Calculate Punching shear area. (A_p)



المحيط العمق

$$A_p = \left[2(a+d)+2(b+d)\right] * d \quad (mm^2)$$

* Calculate Actual Punching shear stress. q_{pu}

$$q_{pu} = \frac{\text{Punching Force}}{\text{Punching area}}$$

$$q_{pu} = \frac{Q_p\ (kN) * 10^3}{\left[2(a+d)+2(b+d)\right] * d} \quad (N/mm^2)$$

* Calculate allowable Punching shear stress. q_{pcu}

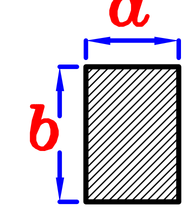
نأخذ القيمه الاقل من الاربع قيم التاليه .

$$q_{pcu} = 0.8\left(\frac{\alpha\, d}{b_o} + 0.2\right)\sqrt{\frac{F_{cu}}{\gamma_c}}$$

$\alpha = 4$ Interior Col.
$\alpha = 3$ Edge Col.
$\alpha = 2$ Corner Col.

b_o هو محيط الخرسانه التى سيحدث لها punching

$$q_{pcu} = 0.316\left(0.5 + \frac{a}{b}\right)\sqrt{\frac{F_{cu}}{\gamma_c}} \quad (N/mm^2)$$



a هو العرض الصغير للعمود

$$q_{pcu} = 0.316\sqrt{\frac{F_{cu}}{\gamma_c}} \quad (N/mm^2)$$

$$q_{pcu} = 1.60 \quad (N/mm^2)$$

* Compare between

Actual punching shear stress (q_{pu}) & Allowable punching shear stress (q_{pcu})

* IF $q_{pu} \leqslant q_{pcu}$ $\longrightarrow$ Safe punching shear. No need to increase dimensions.

* IF $q_{pu} > q_{pcu}$ $\longrightarrow$ UnSafe punching shear. We have to increase dimensions.

5- Reinforcement of the Footing.

From Step ② We Choose $C_1 = (3.5 \rightarrow 5.0)$

From $C_1 \xrightarrow{Get} J$

Get

$$A_s = \frac{M_{act.}}{J\, F_y\, d} \quad (mm^2)$$

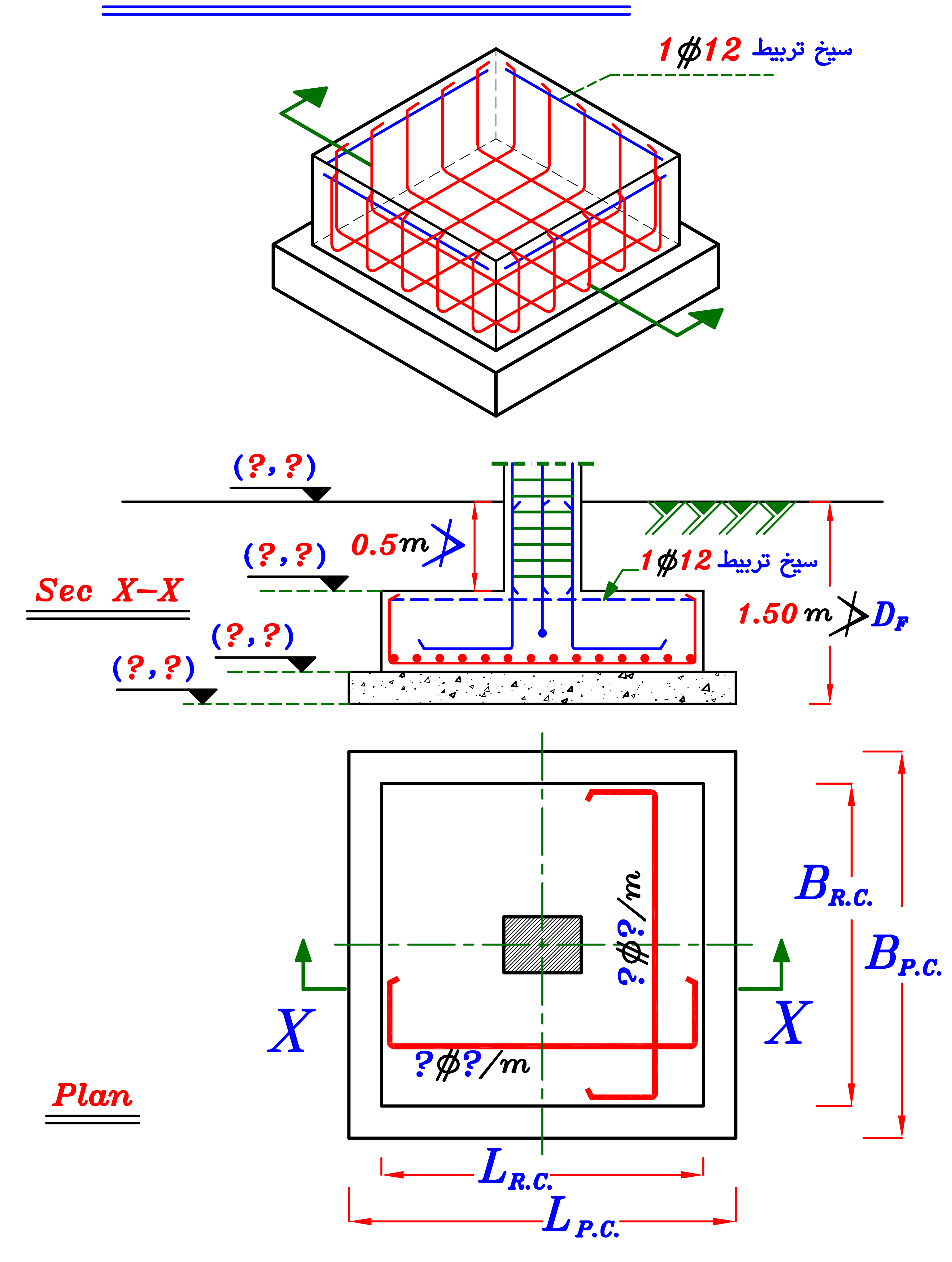
Check $A_{s_{min}}$

$$A_{s_{min}} \; (mm^2/m) = \begin{cases} 1.5\, d \; (mm) \\ 5 \phi 12 / m' \end{cases} \text{الأكبر}$$

IF $A_s \geqslant A_{s_{min}} \longrightarrow$ o.k.

IF $A_s < A_{s_{min}} \longrightarrow$ Take $A_s = A_{s_{min}}$

6- Details of Reinforcement.



Example.

It is required to design a square Footing to Support a R.C column of thickness (45 * 60) cm. The column working load is 1450 kN, and the allowable net bearing capacity in the Footing site is 150 kN/m². (F_{cu} = 25 N/mm², F_y = 360 N/mm²). and draw details of RFT. to scale 1:50

Solution.

Data given.

column dimensions (450 * 600) mm

$P_{col.}(working) = 1450$ kN $P_{col.}(U.L.) = 1450 * 1.5 = 2175$ kN

Bearing capacity of the soil $= q_{all} = 150$ kN/m²

$F_{cu} = 25$ N/mm² $F_y = 360$ N/mm²

1- Calculate the Footing area (Width of R.C. Footing.)

Choose $t_{P.C.} = 40\ cm > 20\ cm$

$$A_{P.C.} = \frac{P_w}{q_{all}} = \frac{1450\ (kN)}{150\ (kN/m^2)} = 9.67\ m^2$$

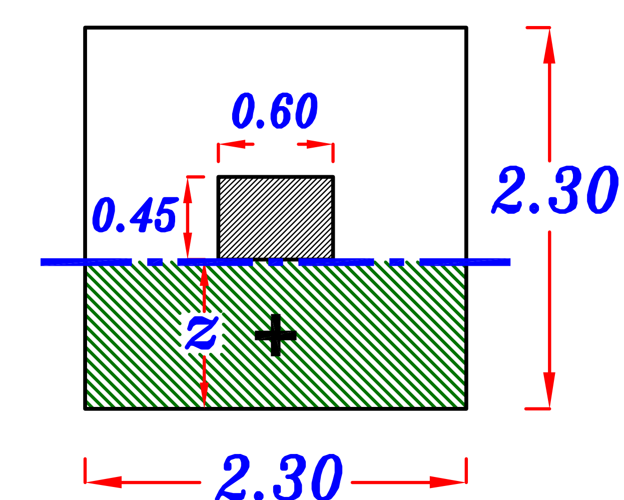
$$A_{P.C.} = B_{P.C.} * B_{P.C.} = 9.67\ m^2$$

$B_{P.C.} = 3.10\ m$ $B_{R.C.} = 2.30\ m$

2– Design the critical sections For moment. (Depth of R.C. Footing.)

– Actual Normal stress on R.C. Footing (U.L.)

$$F_{act.} = \frac{P_{U.L.}}{B_{R.C.} * B_{R.C.}} = \frac{2175}{2.30 * 2.30} = 411.1 \ kN/m^2$$



$$Z = \frac{B_{R.C.} - a}{2} = \frac{2.30 - 0.45}{2}$$

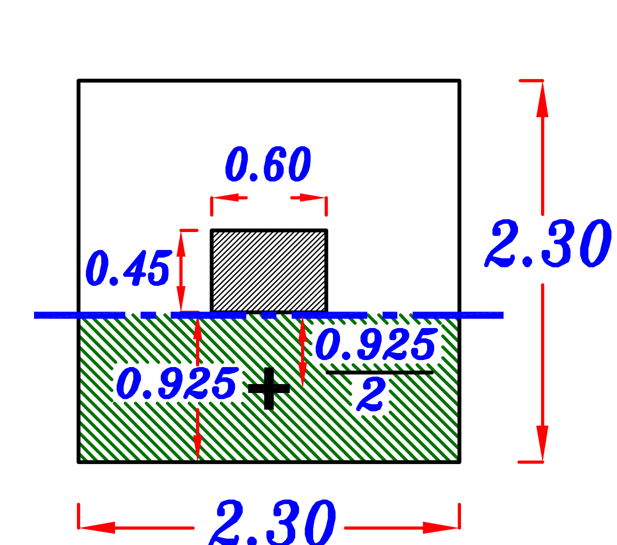
$$= 0.925 \ m$$

$$Force = Stress * Area$$

$$Force = F_{act.} * Z * B$$

$$= 411.1 * 0.925 * 2.30$$

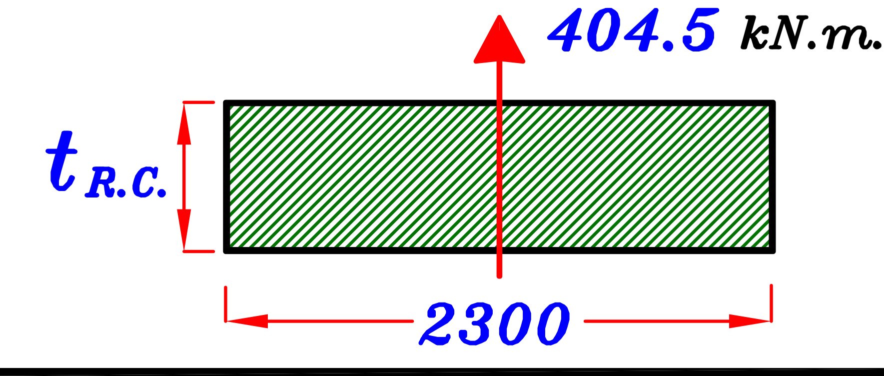
$$= 874.6 \ kN$$



$$moment = Force * Distance$$

$$M_{act.} = (F_{act.} * Z * B_{R.C.}) \frac{Z}{2}$$

$$= (411.1 * 0.925 * 2.30) \frac{0.925}{2} = 404.5 \ kN.m$$



$$\because \ d = C_1 \sqrt{\frac{M_{act.}}{F_{cu} * b}}$$

Choose $C_1 = 5.0$

$$\therefore \ d = 5.0 \sqrt{\frac{404.5 * 10^6}{25 * 2300}} = 419.36 \ mm$$

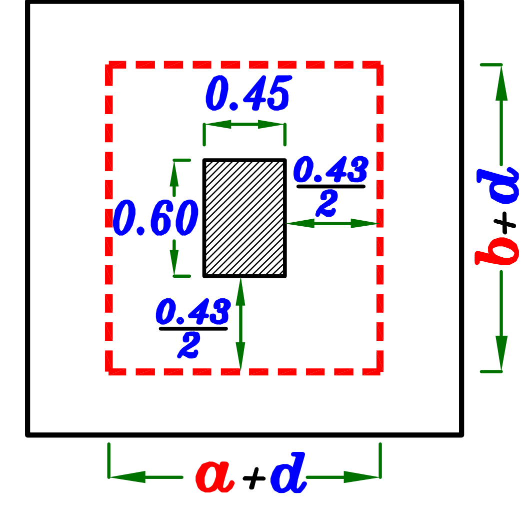
$$t_{R.C.} = d + 70 \ mm = 419.36 + 70 = 489.3 \ mm$$

$t_{R.C.} = 500 \ mm$ **$d = 430 \ mm$**

3- Check Shear.

$$a + d = 0.45 + 0.43 = 0.88 \ m$$

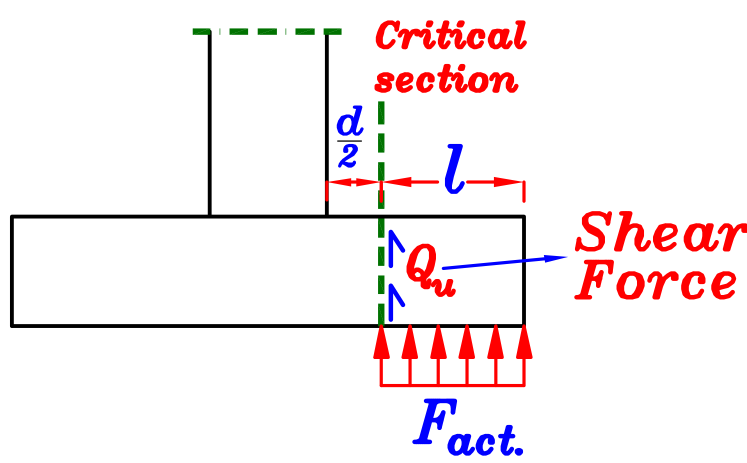
$$b + d = 0.60 + 0.43 = 1.03 \ m$$



*** Critical section For Shear.**

$$l = z - \frac{d}{2}$$

$$l = 0.925 - \frac{0.43}{2} = 0.71 \ m$$



*** Actual shear Force. (Q_u)**

$$Q_u = F_{act.} * l * B_{R.C.} = 411.1 * 0.710 * 2.30 = 671.3 \ kN$$

* Calculate Actual shear stress. (q_u)

$$q_u = \frac{Q_u}{b * d} = \frac{671.3 * 10^3}{2300 * 430} = 0.678 \ N/mm^2$$

* Allowable shear stress. (q_{su})

$$q_{su} = 0.16\sqrt{\frac{F_{cu}}{\delta_c}} = 0.16\sqrt{\frac{25}{1.5}} = 0.653 \ N/mm^2$$

$q_u > q_{su}$ → UnSafe shear
we have to increase dimensions.

Take $t_{R.C.} = 600 \ mm$ $d = 530 \ mm$

3- Check Shear.

$$a + d = 0.45 + 0.53 = 0.98 \ m$$

$$b + d = 0.60 + 0.53 = 1.13 \ m$$

* Critical section For Shear.

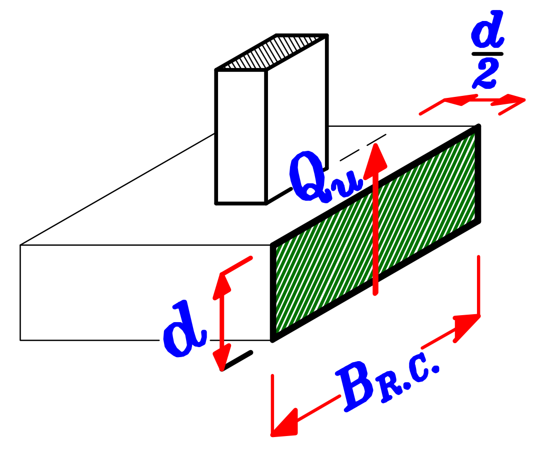
$$l = z - \frac{d}{2}$$

$$l = 0.925 - \frac{0.53}{2} = 0.66 \ m$$

* Actual shear Force. (Q_u)

$$Q_u = F_{act.} * l * B_{R.C.} = 411.1 * 0.66 * 2.30 = 624.05 \ kN$$

* **Calculate Actual shear stress.** (q_u)



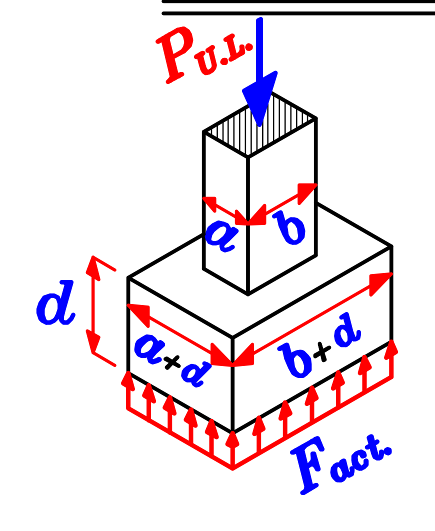
$$q_u = \frac{Q_u}{b * d} = \frac{624.05 * 10^3}{2300 * 530} = 0.512 \ N/mm^2$$

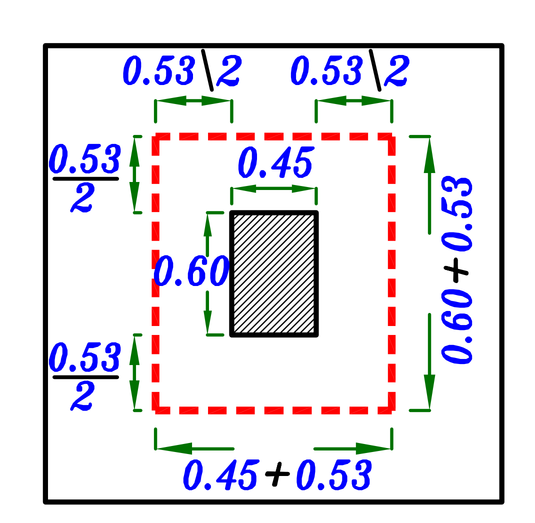
* **Allowable shear stress.** (q_{su})

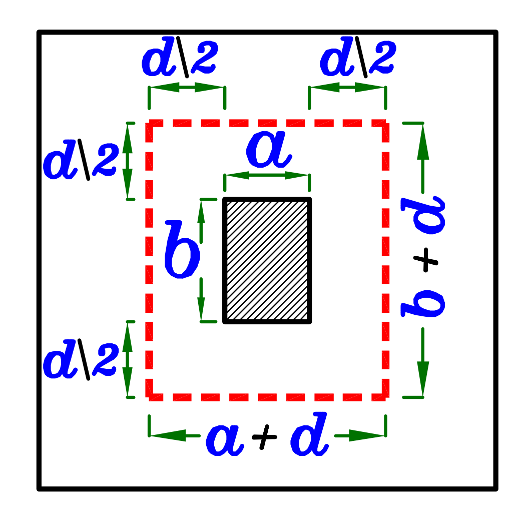
$$q_{su} = 0.16\sqrt{\frac{F_{cu}}{\gamma_c}} = 0.16\sqrt{\frac{25}{1.5}} = 0.653 \ N/mm^2$$

$q_u < q_{su}$ ⟶ Safe shear

4 – Check Punching Shear.







$$a + d = 0.45 + 0.53 = 0.98 \ m$$

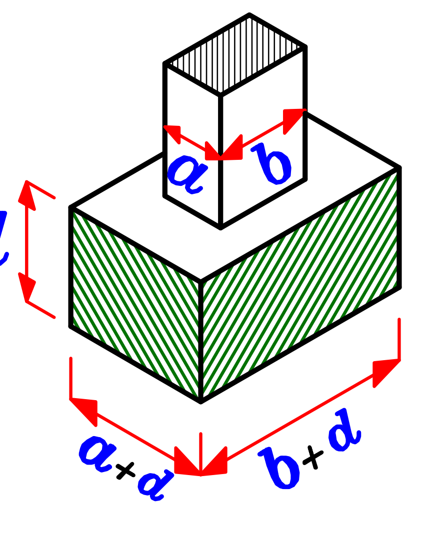
$$b + d = 0.60 + 0.53 = 1.13 \ m$$

* **Calculate Punching Force.** (Q_p)

$$Q_p = P_{U.L.} - (F_{act.}) \left[(a+d)(b+d)\right]$$

$$Q_p = 2175 - 411.1 \left[0.98 * 1.13\right] = 1719.7 \ kN$$

* Calculate Punching shear area. (A_p)



$$A_p = [2(a+d)+2(b+d)] * d$$

$$A_p = [2(450+530)+2(600+530)] * 530$$

$$A_p = 2236600 \ mm^2$$

* Calculate Actual Punching shear stress. q_{pu}

$$q_{pu} = \frac{Q_p}{[2(a+d)+2(b+d)] * d}$$

$$q_{pu} = \frac{1719.7 * 10^3}{2236600} = 0.768 \ N/mm^2$$

---

* Calculate allowable Punching shear stress. q_{pcu}

نأخذ القيمه الاقل من الاربع قيم التاليه .

$$q_{pcu} = 0.8 \left(\frac{\alpha \, d}{b_o} + 0.2 \right) \sqrt{\frac{F_{cu}}{\gamma_c}}$$

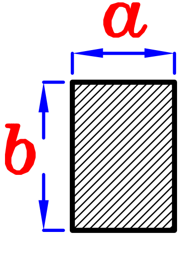
$\alpha = 4$ Interior Col.

$$b_o = 2(a+d)+2(b+d)$$

$$= 2(450+530)+2(600+530) = 4220 \ mm$$

$$q_{pcu} = 0.8 \left(\frac{4 * 530}{4220} + 0.2 \right) \sqrt{\frac{25}{1.5}} = 2.29 \ N/mm^2$$

$$q_{pcu} = 0.316 \left(0.5 + \frac{a}{b}\right) \sqrt{\frac{F_{cu}}{\gamma_c}} \quad (N/mm^2)$$



$a = 0.45\ m$, $b = 0.60\ m$

$$q_{pcu} = 0.316 \left(0.5 + \frac{0.45}{0.60}\right) \sqrt{\frac{25}{1.5}} = 1.61\ N/mm^2$$

$$q_{pcu} = 0.316 \sqrt{\frac{F_{cu}}{\gamma_c}} \quad (N/mm^2)$$

$$q_{pcu} = 0.316 \sqrt{\frac{25}{1.5}} = 1.29\ N/mm^2$$

$$q_{pcu} = 1.60 \quad (N/mm^2)$$

نأخذ القيمه الاقل من الاربع قيم السابقه .

$$\therefore \quad q_{pcu} = 1.29\ N/mm^2$$

$$q_{pu} = 0.768\ N/mm^2$$

$q_{pu} \leqslant q_{pcu} \longrightarrow$ **Safe punching shear.**
No need to increase dimensions.

5- Reinforcement of the Footing.

From $C_1 = 5.0 \longrightarrow J = 0.826$

$$A_s = \frac{M_{act.}}{J\,F_y\,d} = \frac{404.5 * 10^6}{0.826 * 360 * 530} = 2566.6\ mm^2$$

$$A_{s\,(mm^2/m)} = \frac{A_s}{B_{R.C.}} = \frac{2566.6}{2.30} = 1115.9\ mm^2/m`$$

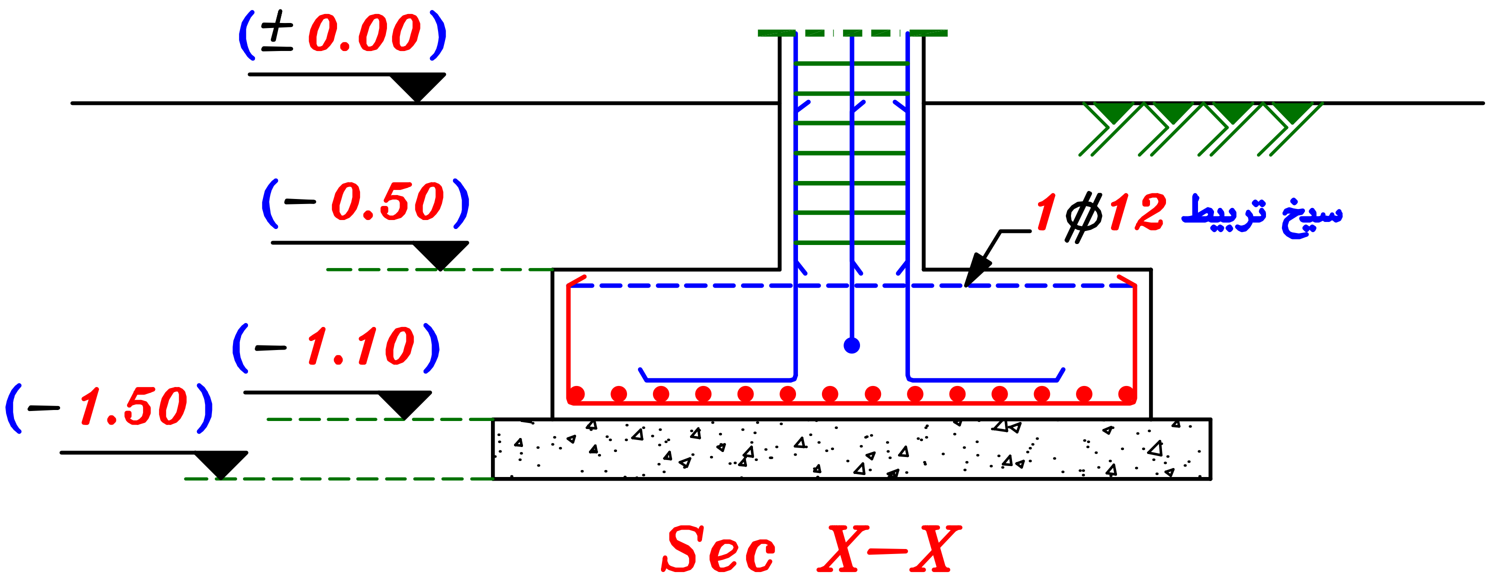
Check $A_{s_{min}}$

$$A_{s_{min}} = \begin{Bmatrix} 1.5\,d = 1.5 * 530 = 795 \\ 5\phi 12/m` = 565 \end{Bmatrix} 795\,mm^2$$

$$\therefore\ A_s > A_{s_{min}} \longrightarrow o.k.$$

$A_s = 1115.9\ mm^2$ **$6\phi 16/m`$**

6- Details of Reinforcement.



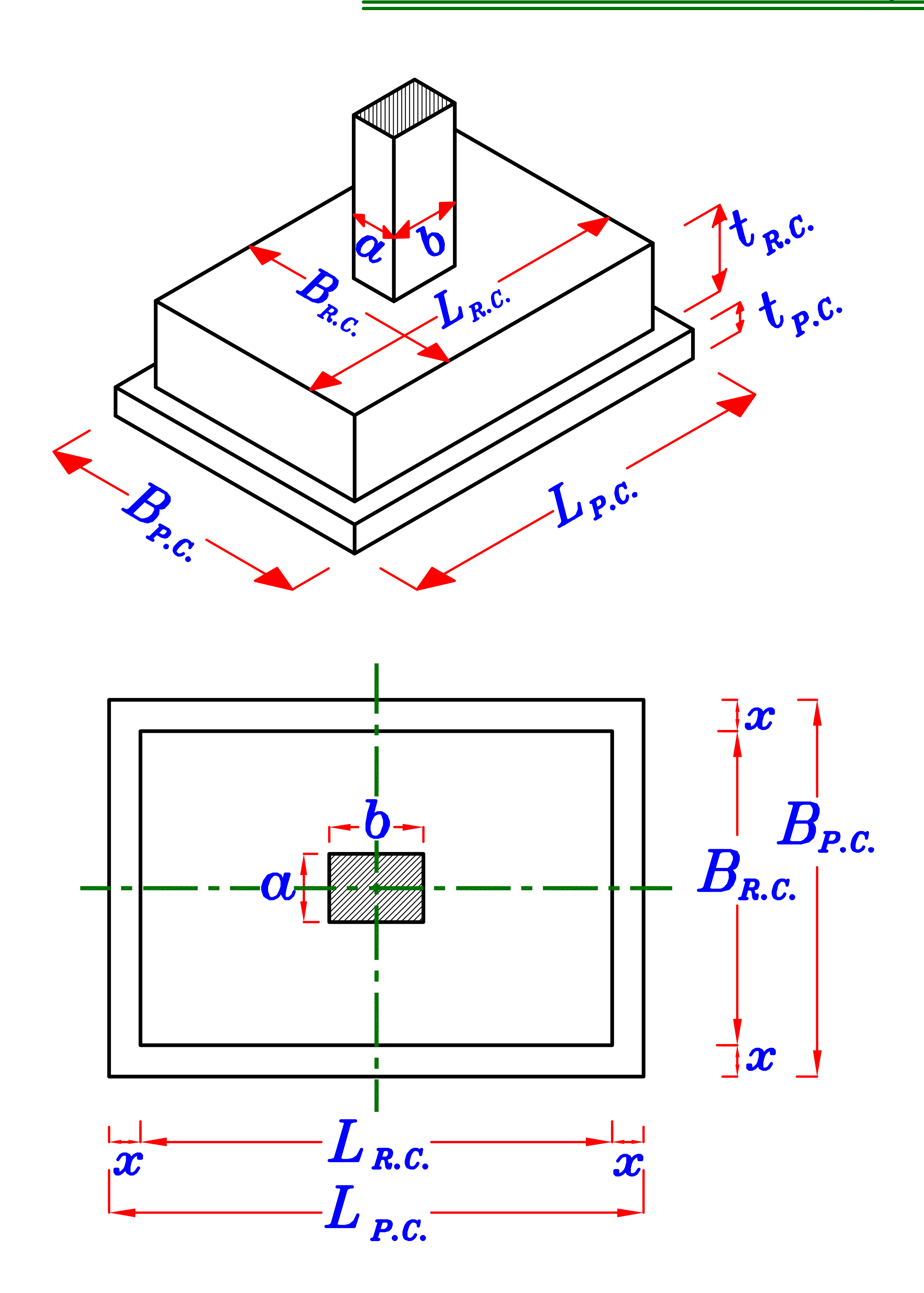


X X
6ϕ16/m'
6ϕ16/m'
2.30
3.10
2.30
3.10

Plan

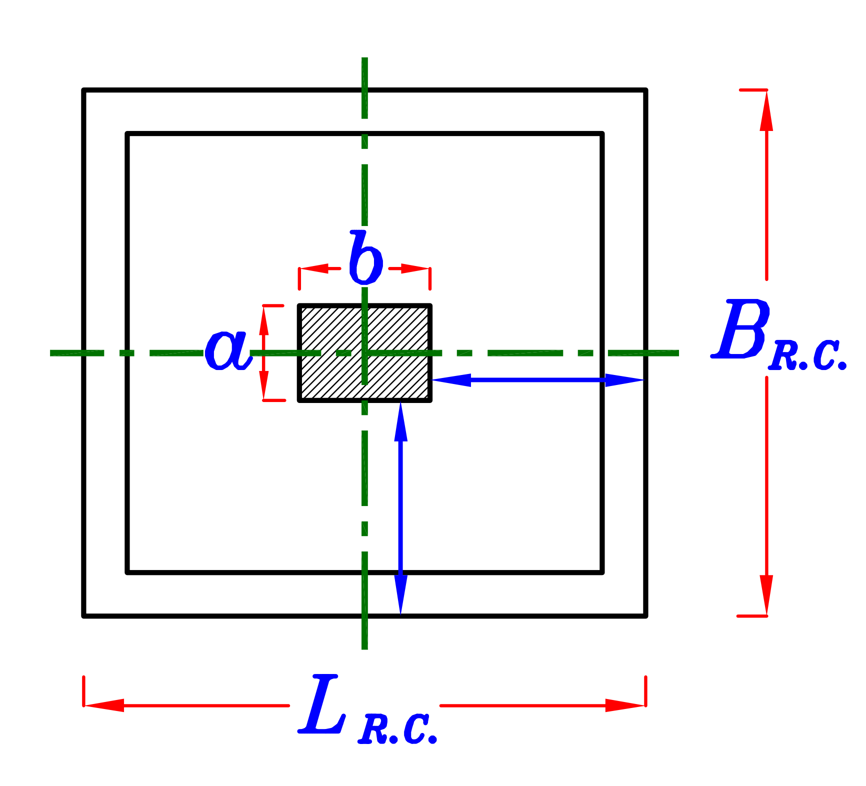
3 Design of Isolated Rectangular Footings.

تصميم القواعد المنفصله المستطيله .



ملحوظه

يفضل فى القواعد المستطيله .
أن تكون المسافه من وش القاعده المسلحه لوش العمود متساويه من الجهتين .
و هذا ليس شرط.



$$L_{P.C.} - B_{P.C.} = b - a$$

1- Calculate the Footing area. (Width & Length of R.C. Footing.)

IF $t_{P.C.} \geq 20\ cm$

get $B_{P.C.}$, $L_{P.C.}$ From

$$A_{P.C.} = \frac{P_w}{q_{all}} = \checkmark\checkmark\ m^2 = B_{P.C.} * L_{P.C.} \quad ------(1)$$

$$L_{P.C.} - B_{P.C.} = b - a \quad ------(2)$$

بعد حساب $B_{P.C.}$ & $L_{P.C.}$ يقربا لاقرب ٥٠ مم بالزياده

$$B_{R.C.} = B_{P.C.} - 2\ t_{P.C.}$$

$$L_{R.C.} = L_{P.C.} - 2\ t_{P.C.}$$

IF $t_{P.C.} < 20\ cm$

get $B_{R.C.}$, $L_{R.C.}$ From

$$A_{R.C.} = \frac{P_w}{q_{all}} = \checkmark\checkmark\ m^2 = B_{R.C.} * L_{R.C.} \quad \text{------} (1)$$

$$L_{R.C.} - B_{R.C.} = b - a \quad \text{------} (2)$$

بعد حساب $B_{R.C.}$ & $L_{R.C.}$ يقربا لاقرب ٥٠ مم بالزياده

$$B_{P.C.} = B_{R.C.} + 2\ t_{P.C.}$$

$$L_{P.C.} = L_{R.C.} + 2\ t_{P.C.}$$

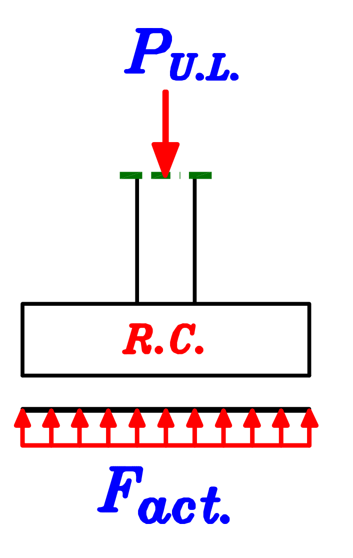
2- Design the critical sections For moment. (Depth of R.C. Footing.)

$B_{R.C.} = \checkmark\ m$, $L_{R.C.} = \checkmark\ m$

$$P_{U.L.} = P_w * 1.5 \quad (kN)$$

- Actual Normal stress on R.C. Footing (U.L.)

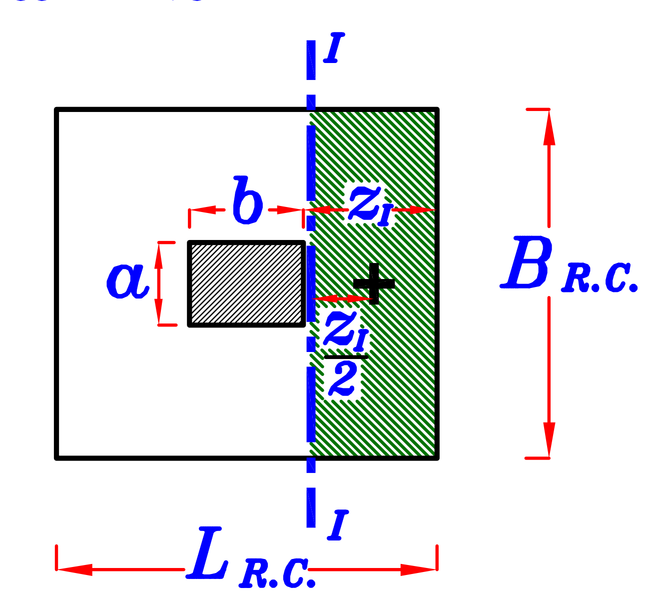
$$F_{act.} = \frac{P_{U.L.}}{B_{R.C.} * L_{R.C.}} \quad (kN/m^2)$$



- *Critical section of bending at R.C. Foorting.*

ناخذ القطاعات الحرجه للعزوم على وش العمود من الجهتين .

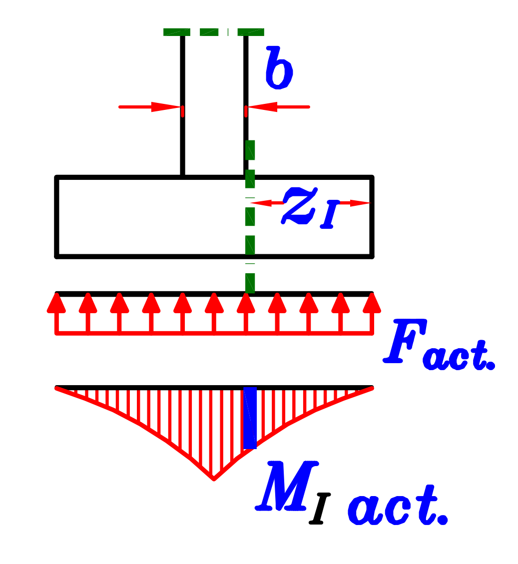
Direction I



$$z_I = \frac{L_{R.C.} - b}{2} \quad (m)$$

Force = Stress * Area

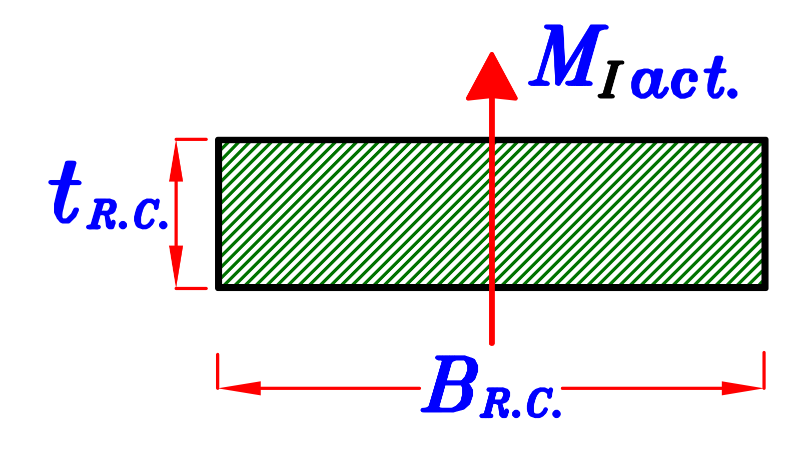
$$Force = F_{act.} * z_I * B_{R.C.}$$

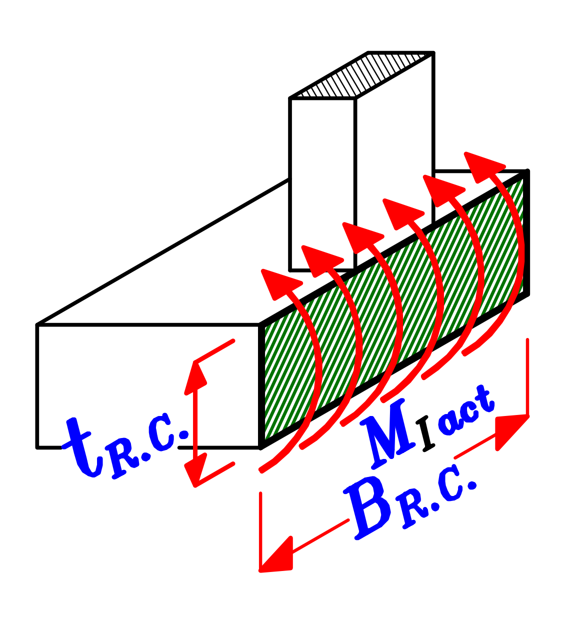


Moment = Force * Distance

$$M_{I\,act.} = (F_{act.} * z_I * B_{R.C.}) \frac{z_I}{2}$$

(kN.m./B)





$$d_{I\,(mm)} = C_1 \sqrt{\frac{M_{I\,act.}\,(kN.m) * 10^6}{F_{cu}\,(N/mm^2) * B_{R.C.}\,(mm)}}$$

Choose $C_1 = (3.5 \rightarrow 5.0)$

يفضل فى القواعد أن نختار قيمه كبيره ل C_1 حتى تكون تخانه القاعده كبيره لضمان أن تكون القاعده **Rigid**

Get $d_I = ✓✓$ (mm)

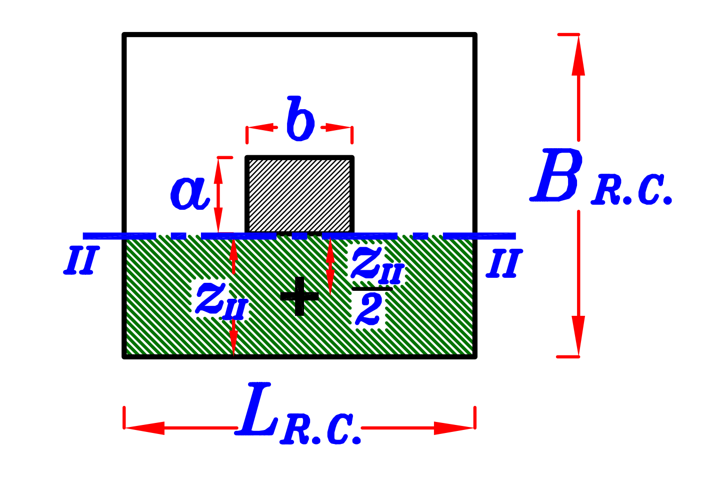
Take cover = 70 mm

يفضل أن يكون ال **cover** فى القواعد كبير لحمايه الحديد من الصدأ .

$$t_{I\,R.C.} = d_I + cover \quad (70\ mm)$$

تقرب لاقرب ٥٠ مم بالزياده

Direction II



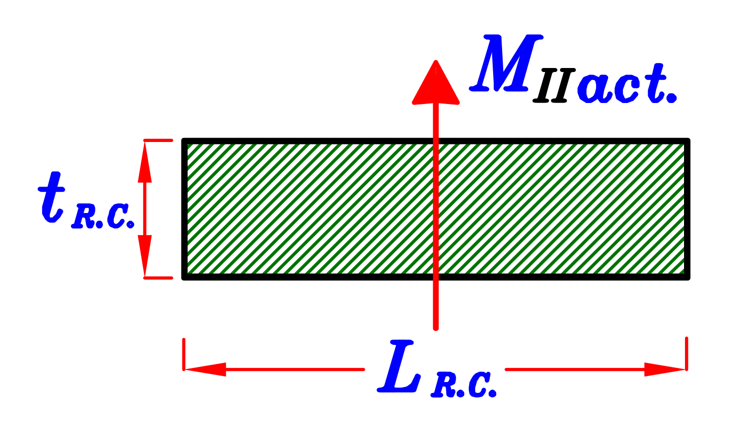
$$z_{II} = \frac{B_{R.C.} - a}{2} \quad (m)$$

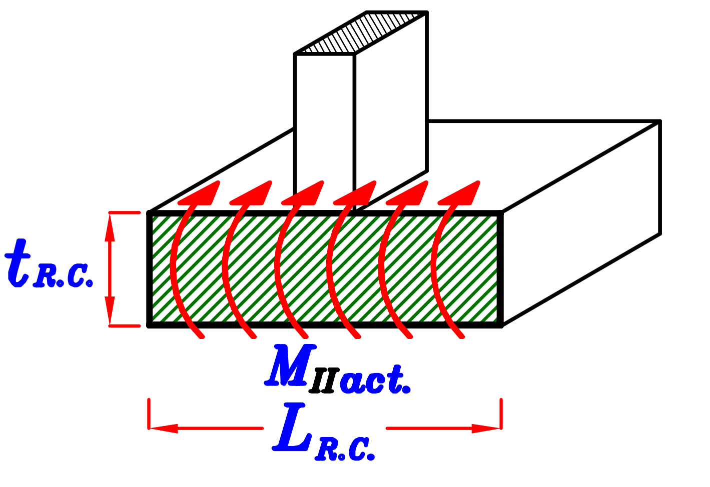
Force = Stress * Area

$$Force = F_{act.} * z_{II} * L_{R.C.}$$

Moment = Force * Distance

$$M_{II\,act.} = (F_{act.} * z_{II} * L_{R.C.})\,\frac{z_{II}}{2} \quad (kN.m./L)$$





$$d_{II}\ (mm) = C_1 \sqrt{\frac{M_{II\,act.}\ (kN.m) * 10^6}{F_{cu}\ (N/mm^2) * L_{R.C.}\ (mm)}}$$

Choose $C_1 = (3.5 \rightarrow 5.0)$

Get $d_{II} = ✓✓\ (mm)$

Take $cover = 70\ mm$

يفضل فى القواعد أن نختار قيمه كبيره لـ C_1
حتى تكون تخانه القاعده كبيره
لضمان أن تكون القاعده Rigid

يفضل أن يكون الـ cover فى القواعد كبير
لحمايه الحديد من الصدأ .

$$t_{II_{R.C.}} = d_{II} + cover\ (70\ mm)$$

تقرب لاقرب ٥٠ مم بالزياده

نأخذ الاكبر من $t_{II_{R.C.}}$ & $t_{I_{R.C.}}$ تكون هى $t_{R.C.}$

ملحوظه

اذا حافظنا على الشرط $L_{P.C.} - B_{P.C.} = b - a$

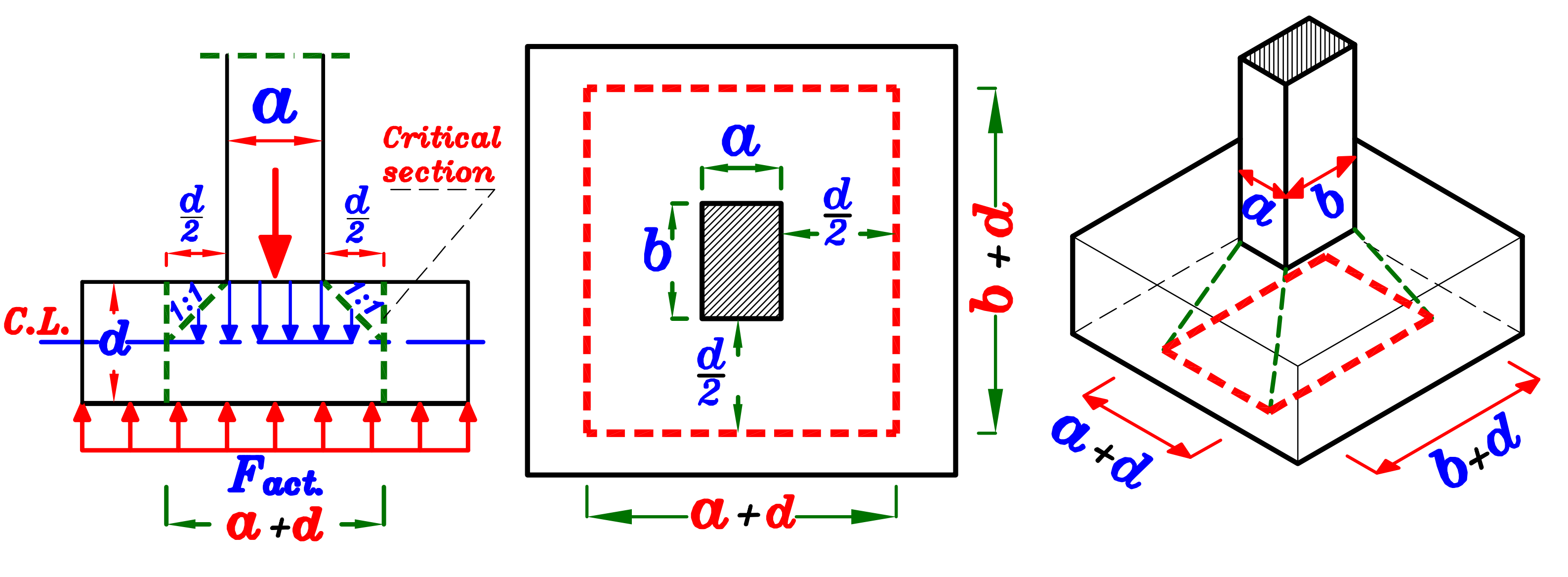
فيكون $z_I = z_{II}$ و بالتالى سيكون $\frac{M_I}{B} = \frac{M_{II}}{L}$ و من ثم سيكون $d_I = d_{II}$

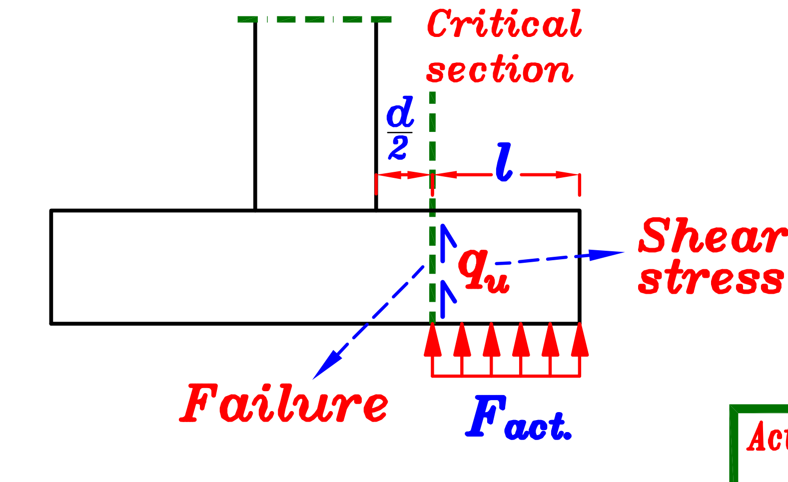
أى انه يمكن أن ندرس أتجاه واحد فقط و يكون الاخر بالمثل .

3 – Check Shear.

Critical section of shear at R.C. Footing.

حمل العمود يتوزع من أعلى الى أسفل داخل القاعده بميل (1:1) أى بزاويه ميل 45^{o}
أى يكون تأثيره على القاعده على عرض $(b+d)$ & $(a+d)$
فتكون المساحه $(b+d) * (a+d)$ فى منتصف القاعده عليها أقل اجهادات قص
حيث تكون قيمته تساوى رد فعل التربه على القاعده $F_{act.}$ مطروحا منه حمل العمود $P_{U.L.}$
فيكون القطاع الحرج الذى عليه أكبر اجهادات قص على بعد $\frac{d}{2}$ من وش العمود من أى جهه
لانه أول قطاع عليه رد فعل الارض فقط و بالتالى يكون عليه أكبر Shear stress .

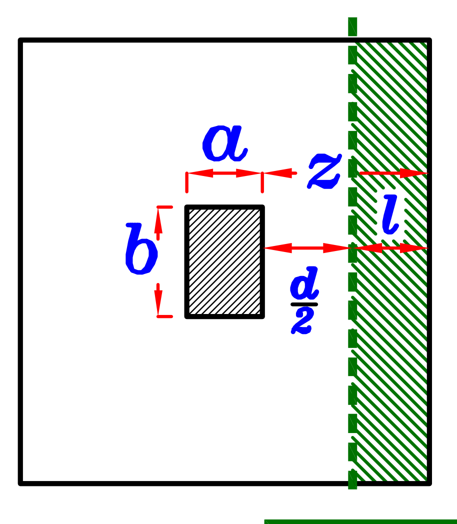


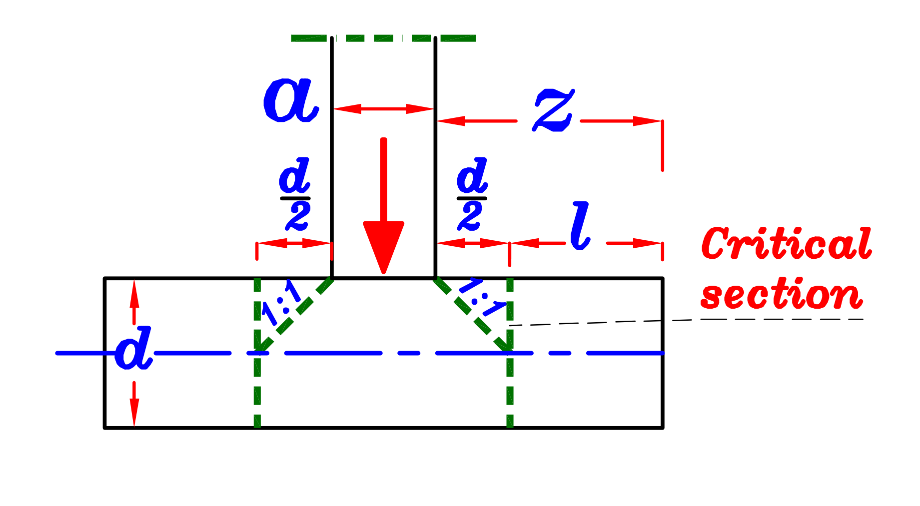


[Shear Failure]

لذلك يجب التحقق من أن اجهاد القص
على جانب السطح المتوقع للانفصال
لا يتعدى مقاومه الخرسانه فى القص

Actual Shear stress	$\leq$	Allowable Shear stress
q_u	$\leq$	q_{su}





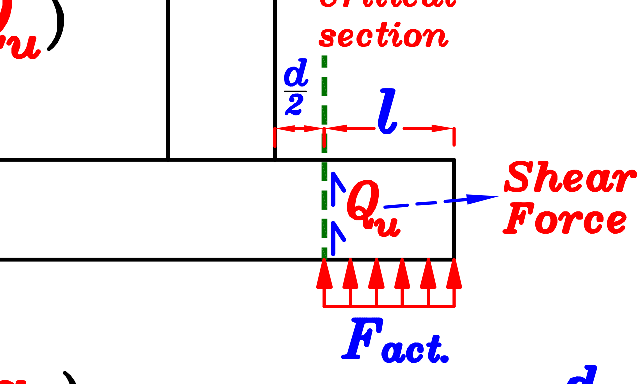
* Calculate $l = z - \frac{d}{2}$ (m)

z الاكبر من z_I , z_{II}

* Calculate Actual shear Force. (Q_u)

نحسب ل ١,- م طولى من القاعده

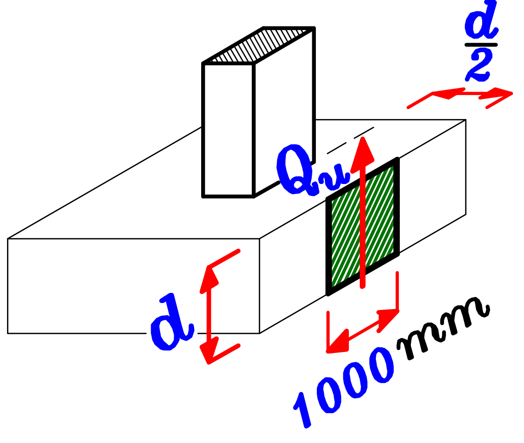
$$Q_u = F_{act.} * l * 1.0\ m \quad (kN)$$



* Calculate Actual shear stress. (q_u)

$$q_u = \frac{Q_u}{b * d}$$

$$q_u = \frac{Q_{u\,(kN)} * 10^3}{1000\,(mm) * d\,(mm)} \quad (N/mm^2)$$



* Calculate Allowable shear stress. (q_{su})

$$q_{su} = 0.16 \sqrt{\frac{F_{cu}}{\gamma_c}} \quad (N/mm^2)$$

لاحظ أنه فى القواعد نعتمد فقط على مقاومه الخرسانه فى القص لانه لا توجد كانات حيث يصعب تشكيلها بالابعاد الضخمه للقواعد .

* Compare between

Actual shear stress (q_u) & Allowable shear stress (q_{su})

* IF $q_u \leqslant q_{su} \longrightarrow$ Safe shear stresses
No need to increase dimensions.

* IF $q_u > q_{su} \longrightarrow$ UnSafe shear stresses
We have to increase dimensions.

IF UnSafe shear stresses increase $t_{R.C.}$ by 100 mm

then Calculate:

$$d = t_{R.C.} - 70 \text{ mm}$$

$$l = z - \frac{d}{2} \quad (m)$$

$$Q_u = F_{act.} * l * 1.0 \, m \quad (kN)$$

$$q_u = \frac{Q_u (kN) * 10^3}{1000 (mm) * d (mm)} \quad (N/mm^2)$$

then ReCheck:

Actual shear stress (q_u) & Allowable shear stress (q_{su})

4 – Check Punching Shear. القص الثاقب .

يجب التأكد من أن العمود لن يخترق القاعده .

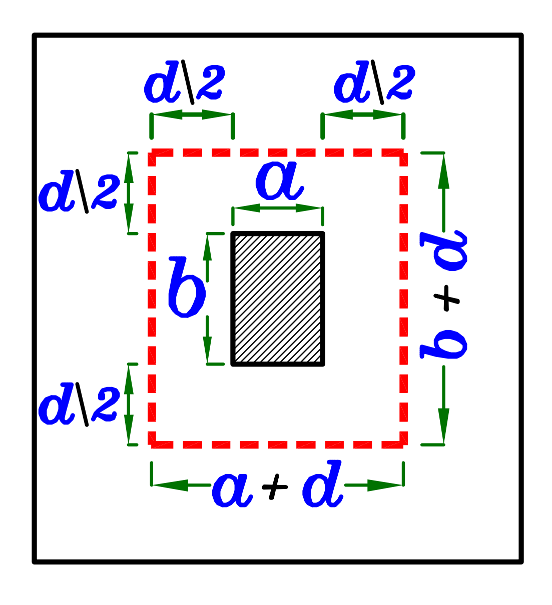
و للتأكد من ذلك نحسب q_{pu} و هو اجهاد القص الذى سينتج عن ثقب العمود للقاعده .

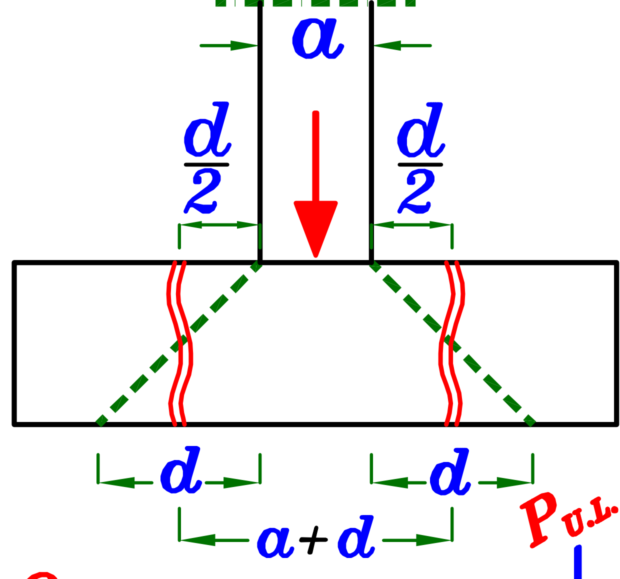
و نحسب q_{pcu} و هى مقاومه الخرسانه للقص الناتج عن ثقب القاعده .

The concrete area which resist punching shear.

تحديد مساحه الخرسانه المقاومه للقص الثاقب .

القطاع الحرج فى القص الثاقب عباره عن محيط يحيط بالعمود على مسافه $\frac{d}{2}$ من وش العمود من كل جهه .





* Calculate Punching Force. (Q_p)

$$Q_p = P_{U.L.} - (F_{act.})\,[(a+d)(b+d)] \quad (kN)$$

$P_{U.L.}$

a b d a+d b+d $F_{act.}$

* Calculate Punching shear area. (A_p)

المحيط   العمق

$$A_p = [2(a+d)+2(b+d)] * d \quad (mm^2)$$

d a b a+d b+d

* Calculate Actual Punching shear stress. q_{pu}

$$q_{pu} = \frac{\text{Punching Force}}{\text{Punching area}}$$

$$q_{pu} = \frac{Q_p\,(kN) * 10^3}{[2(a+d)+2(b+d)] * d} \quad (N/mm^2)$$

* Calculate allowable Punching shear stress. q_{pcu}

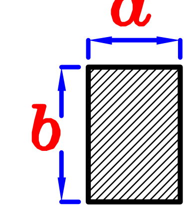
نأخذ القيمه الاقل من الاربع قيم التاليه .

$$q_{pcu} = 0.8\left(\frac{\alpha\, d}{b_o} + 0.2\right)\sqrt{\frac{F_{cu}}{\gamma_c}}$$

$\alpha = 4$ Interior Col.
$\alpha = 3$ Edge Col.
$\alpha = 2$ Corner Col.

b_o هو محيط الخرسانه التى سيحدث لها punching

$$q_{pcu} = 0.316\left(0.5 + \frac{a}{b}\right)\sqrt{\frac{F_{cu}}{\gamma_c}} \quad (N/mm^2)$$



a هو العرض الصغير للعمود

$$q_{pcu} = 0.316\sqrt{\frac{F_{cu}}{\gamma_c}} \quad (N/mm^2)$$

$$q_{pcu} = 1.60 \quad (N/mm^2)$$

---

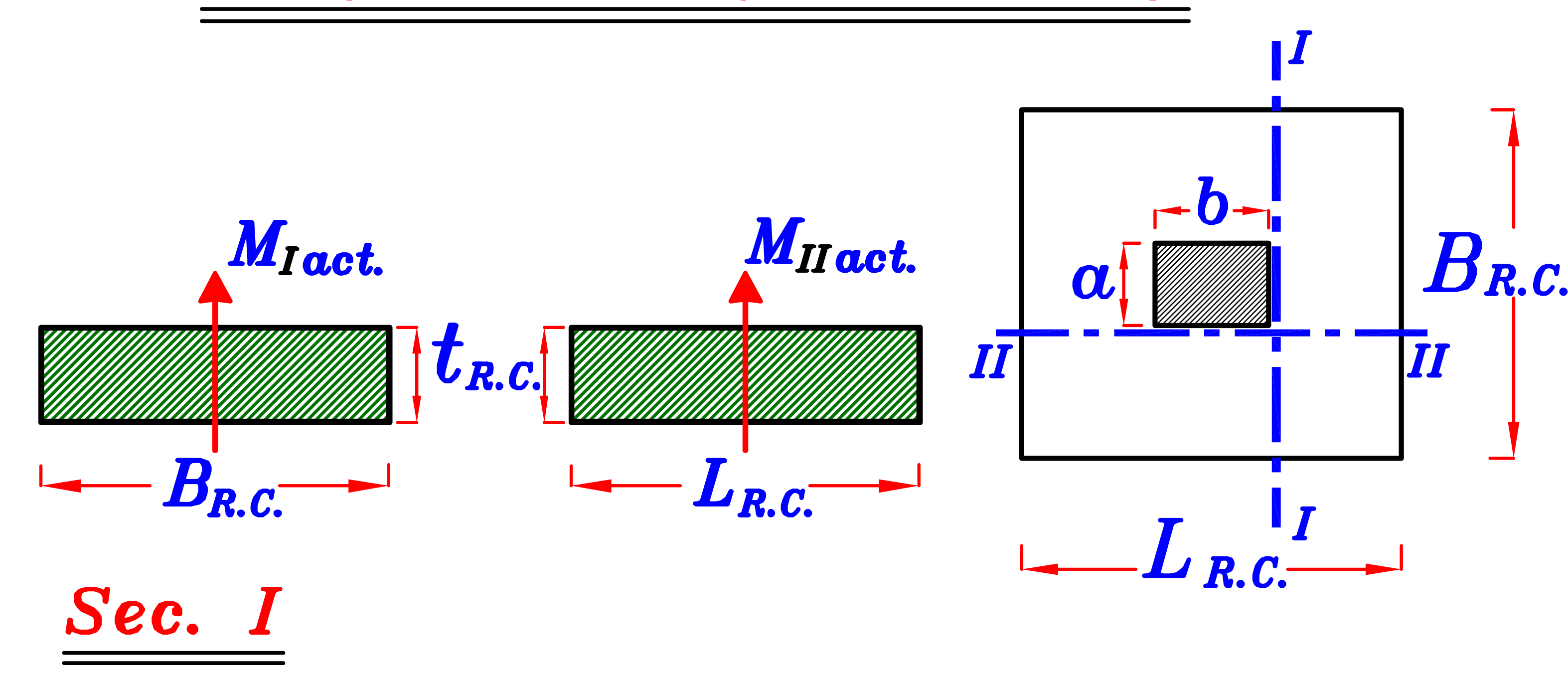
* Compare between

Actual punching shear stress (q_{pu}) & Allowable punching shear stress (q_{pcu})

* IF $q_{pu} \leq q_{pcu}$ ⟶ Safe punching shear. No need to increase dimensions.

* IF $q_{pu} > q_{pcu}$ ⟶ UnSafe punching shear. We have to increase dimensions.

5- Reinforcement of the Footing.



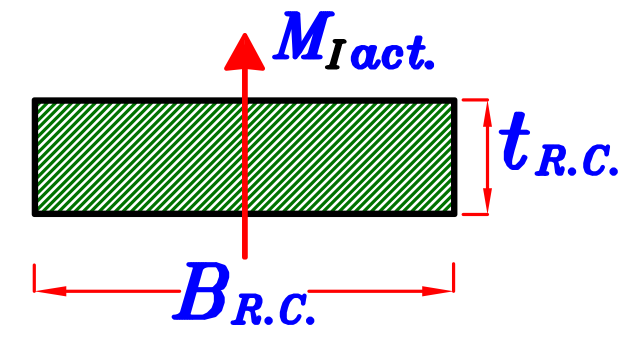
Sec. I

From Step ② We Choose $C_1 = (3.5 \rightarrow 5.0)$

From $C_1 \xrightarrow{Get} J$

Get

$$A_{sI} = \frac{M_{I\,act.}}{J\,F_y\,d} \quad (mm^2)$$



Check $A_{s_{min}}$

$$A_{s_{min}}\ (mm^2/m) = \begin{cases} 1.5\,d\ (mm) \\ 5\,\phi\,12/m' \end{cases} \text{الأكبر}$$

IF $A_{sI} \geqslant A_{s_{min}} \longrightarrow$ o.k.

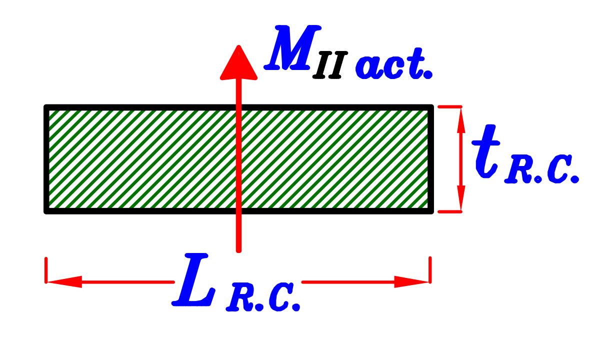
IF $A_{sI} < A_{s_{min}} \longrightarrow$ Take $A_s = A_{s_{min}}$

Sec. II

From Step ② We Choose $C_1 = (3.5 \rightarrow 5.0)$

From $C_1 \xrightarrow{Get} J$

Get $$A_{sII} = \frac{M_{II\,act.}}{J\,F_y\,d} \quad (mm^2)$$



Check $A_{s\,min}$

$$A_{s\,min}\ (mm^2/m) = \begin{Bmatrix} 1.5\,d\ (mm) \\ 5\,\phi\,12/m' \end{Bmatrix} \text{ الأكبر}$$

IF $A_{sII} \geq A_{s\,min} \longrightarrow$ o.k.

IF $A_{sII} < A_{s\,min} \longrightarrow$ Take $A_s = A_{s\,min}$

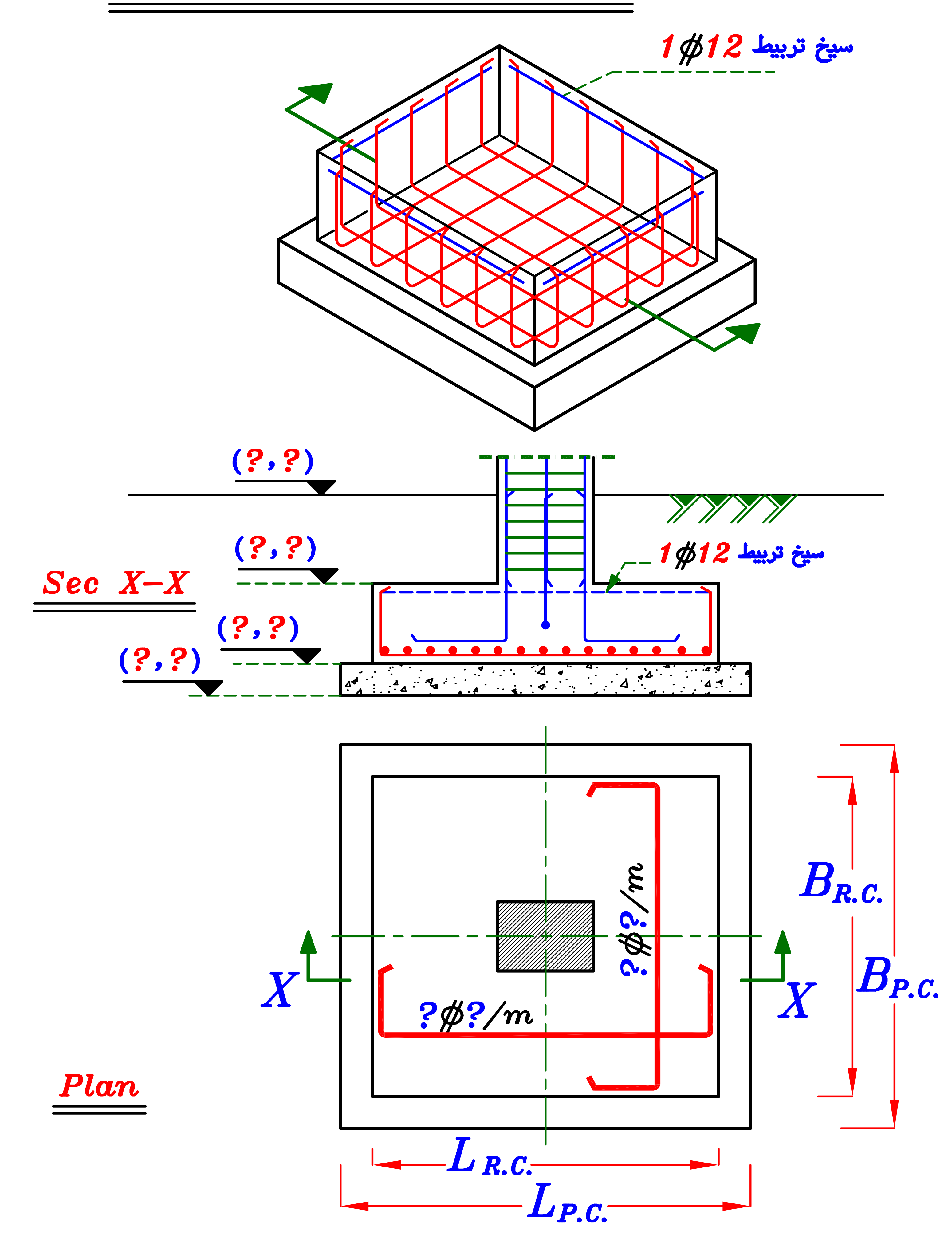
ملحوظه

في حاله تحقيق الشرط $L - B = b - a$

سيكون $\frac{M_{II\,act.}}{L} = \frac{M_{I\,act.}}{B}$ و بالتالى من الممكن حساب A_s فى اتجاه

واحد فقط و يكون الاتجاه الاخر نفس القيمه $A_{sI} = A_{sII}$

6- Details of Reinforcement.



Example.

It is required to design a rectangular Footing to Support a R.C column of thickness (30 * 80) cm.
The column working load is 1900 kN , and the allowable net bearing capacity in the Footing site is 120 kN/m^2. (F_{cu} = 30 N/mm^2, F_y = 400 N/mm^2).
and draw details of RFT. to scale 1:50

Solution.

Data given.

column dimensions (300 * 800) mm

$P_{col.}(working) = 1900$ kN $\qquad P_{col.}(U.L.) = 1900 * 1.5 = 2850$ kN

Bearing capacity of the soil = $q_{all} = 120$ kN/m^2

$F_{cu} = 30$ N/mm^2 $\qquad F_y = 400$ N/mm^2

1– Calculate the Footing area (Width & Length of R.C. Footing.)

Choose $t_{P.C.} = 30\ cm > 20\ cm$

$$L_{P.C.} - B_{P.C.} = b - a = 0.80 - 0.30 = 0.50\ m$$

$$L_{P.C.} = B_{P.C.} + 0.50\ m \quad ------(1)$$

$$A_{P.C.} = \frac{P_w}{q_{all}} = \frac{1900\ (kN)}{120\ (kN/m^2)} = 15.83\ m^2$$

$$A_{P.C.} = B_{P.C.} * L_{P.C.} = 15.83\ m^2 \quad -----(2)$$

$$B_{P.C.} * L_{P.C.} = B_{P.C.} * (B_{P.C.} + 0.50) = 15.83 \ m^2$$

$$B_{P.C.} = 3.73 \ m$$

$$B_{P.C.} = 3.80 \ m \qquad L_{P.C.} = 4.30 \ m$$

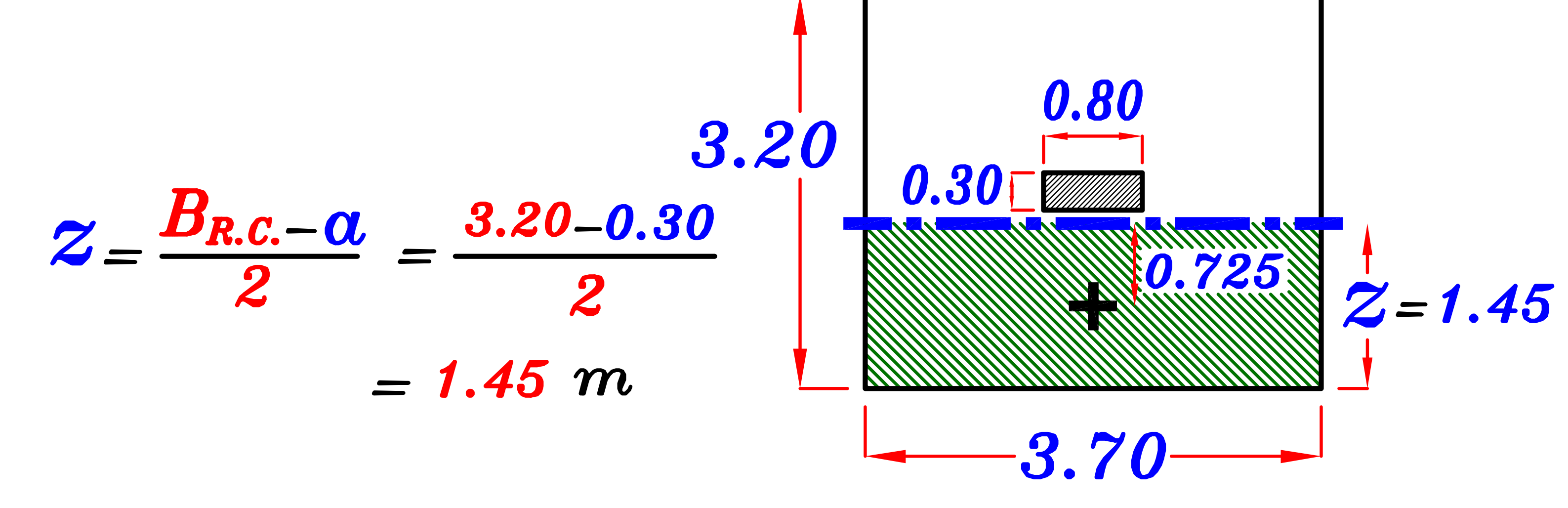
$$B_{R.C.} = 3.20 \ m \qquad L_{R.C.} = 3.70 \ m$$

2- Design the critical sections For moment. (Depth of R.C. Footing)

- Actual Normal stress on R.C. Footing (U.L.)

$$F_{act.} = \frac{P_{U.L.}}{B_{R.C.} * L_{R.C.}} = \frac{2850}{3.20 * 3.70} = 240.7 \ kN/m^2$$

$$z = \frac{B_{R.C.} - a}{2} = \frac{3.20 - 0.30}{2} = 1.45 \ m$$



ملحوظه

اذا حافظنا على الشرط $L_{P.C.} - B_{P.C.} = b - a$

فيكون $z_I = z_{II}$ و بالتالى سيكون $\frac{M_I}{B} = \frac{M_{II}}{L}$ و من ثم سيكون $d_I = d_{II}$

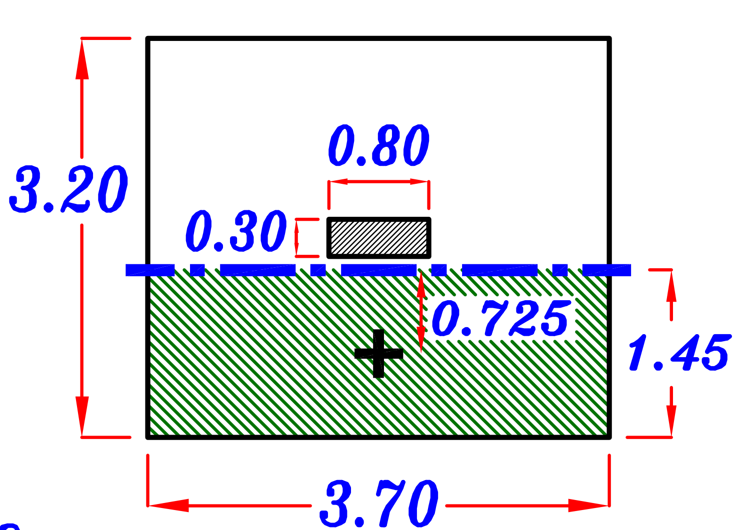
أى انه يمكن أن ندرس أتجاه واحد فقط و يكون الاخر بالمثل .

$$Force = Stress * Area$$

$$Force = F_{act.} * Z * B$$

$$= 240.7 * 1.45 * 3.70$$

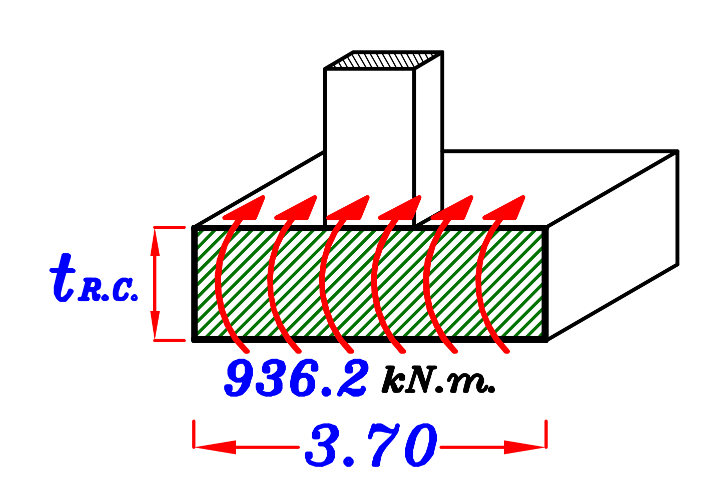
$$= 1291.4 \text{ kN}$$

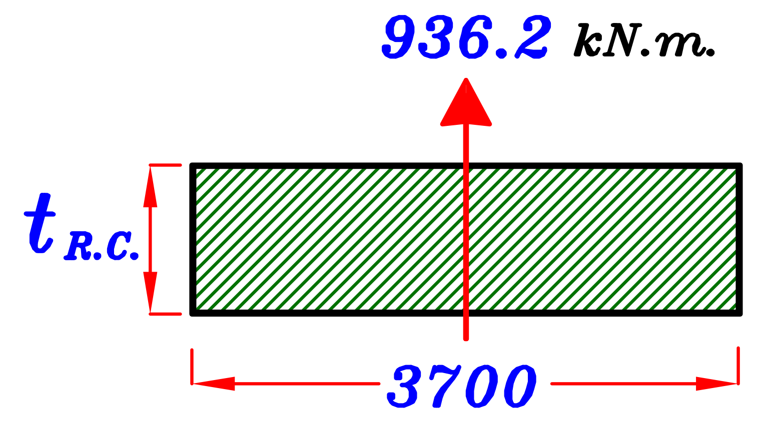


$$moment = Force * Distance$$

$$M_{act.} = (F_{act.} * Z * B_{R.C.}) \frac{Z}{2}$$

$$= (240.7 * 1.45 * 3.70) \frac{1.45}{2} = 936.2 \text{ kN.m}$$





$$\because \; d = C_1 \sqrt{\frac{M_{act.}}{F_{cu} * b}}$$

Choose $C_1 = 5.0$

$$\therefore \; d = 5.0 \sqrt{\frac{936.2 * 10^6}{30 * 3700}} = 459.2 \text{ mm}$$

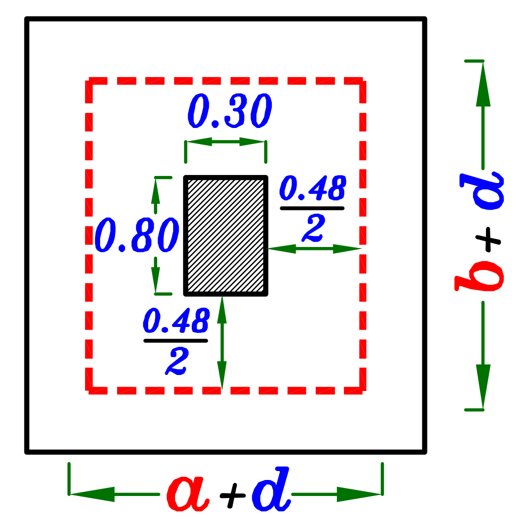
$$t_{R.C.} = d + 70 \text{ mm} = 459.2 + 70 = 529.2 \text{ mm}$$

$t_{R.C.} = 550$ mm **$d = 480$ mm**

3 – Check Shear.

$a + d = 0.30 + 0.48 = 0.78\ m$

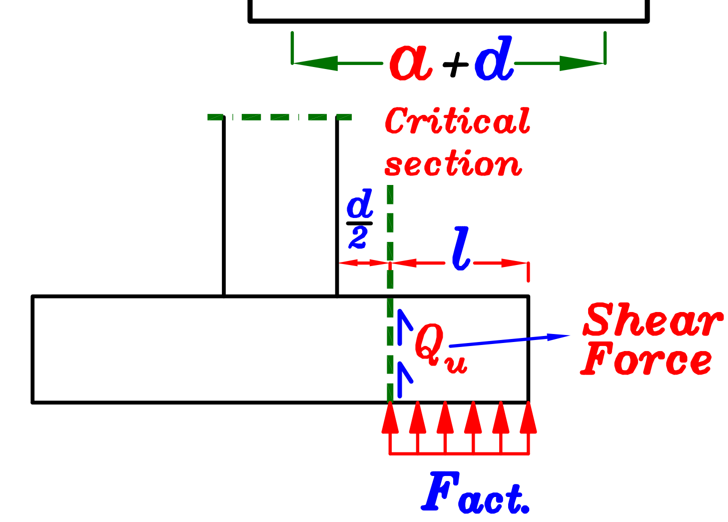
$b + d = 0.80 + 0.48 = 1.28\ m$



* Critical section For Shear.

$$l = z - \frac{d}{2}$$

$$l = 1.45 - \frac{0.48}{2} = 1.21\ m$$

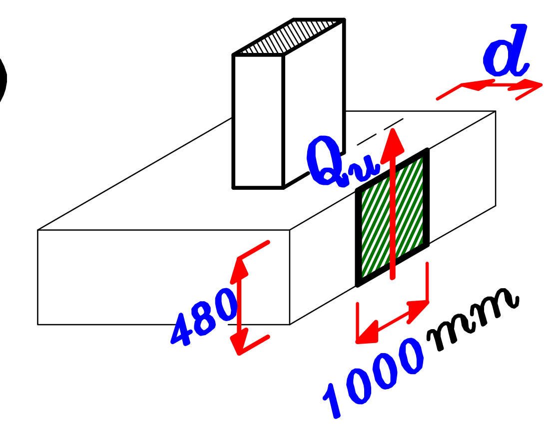


* (Q_u) For 1.0 m

$$Q_u = F_{act.} * l * 1.0\ m = 240.7 * 1.21 * 1.0\ m = 291.2\ kN$$

* Calculate Actual shear stress. (q_u)

$$q_u = \frac{Q_u}{b * d} = \frac{291.2 * 10^3}{1000 * 480} = 0.606\ N/mm^2$$

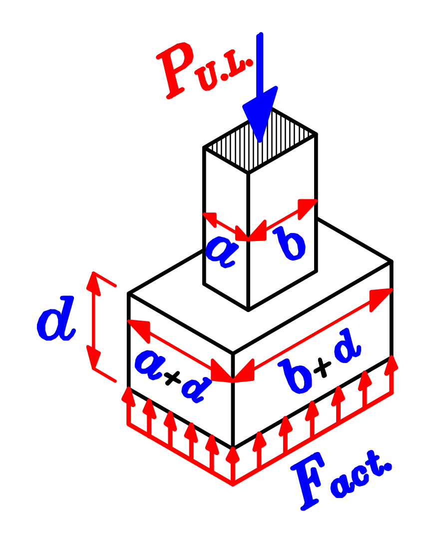


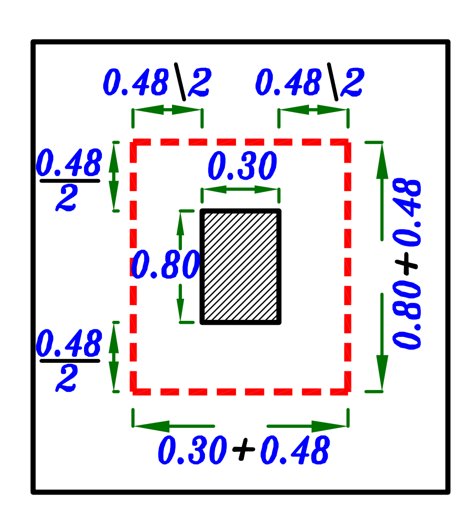
* Allowable shear stress. (q_{su})

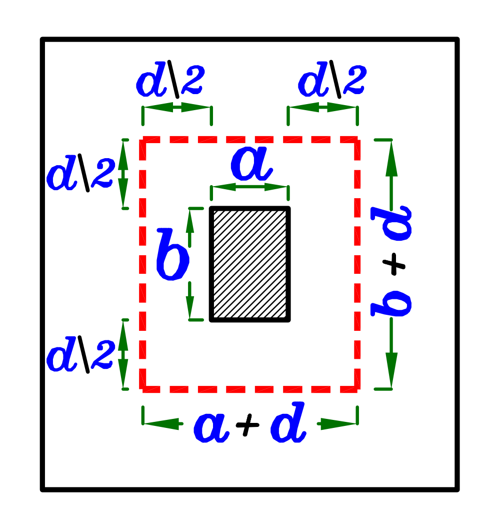
$$q_{su} = 0.16\sqrt{\frac{F_{cu}}{\delta_c}} = 0.16\sqrt{\frac{30}{1.5}} = 0.715\ N/mm^2$$

$q_u < q_{su}$ → Safe shear stresses
No need to increase dimensions.

4- Check Punching Shear.







$$a + d = 0.30 + 0.48 = 0.78\ m$$

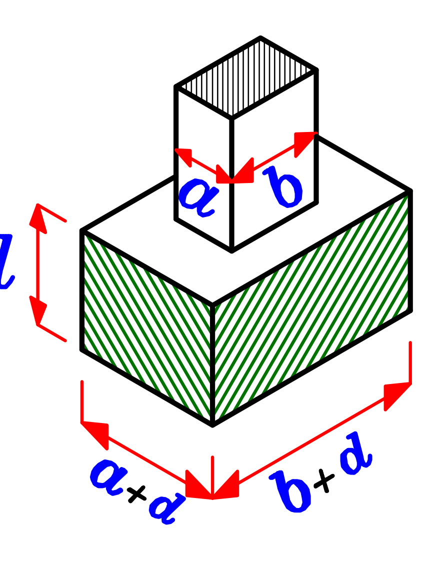
$$b + d = 0.80 + 0.48 = 1.28\ m$$

* **Calculate Punching Force.** (Q_p)

$$Q_p = P_{U.L.} - (F_{act.})\ [(a+d)(b+d)]$$

$$Q_p = 2850 - 240.7\ [0.78 * 1.28] = 2609.7\ kN$$

* **Calculate Punching shear area.** (A_p)



$$A_p = [2(a+d) + 2(b+d)] * d$$

$$A_p = [2(300+480) + 2(800+480)] * 480$$

$$A_p = 1977600\ mm^2$$

* Calculate Actual Punching shear stress. q_{pu}

$$q_{pu} = \frac{Q_p}{[2(a+d)+2(b+d)]*d}$$

$$q_{pu} = \frac{2609.7*10^3}{1977600} = 1.319\ N/mm^2$$

---

* Calculate allowable Punching shear stress. q_{pcu}

نأخذ القيمه الاقل من الاربع قيم التاليه .

$$q_{pcu} = 0.8\left(\frac{\alpha\, d}{b_o} + 0.2\right)\sqrt{\frac{F_{cu}}{\gamma_c}}$$

$\alpha = 4$ Interior Col.

$$b_o = 2(a+d)+2(b+d)$$

$$= 2(300+480)+2(800+480) = 4120\ mm$$

$$q_{pcu} = 0.8\left(\frac{4*480}{4120} + 0.2\right)\sqrt{\frac{30}{1.5}} = 2.38\ N/mm^2$$

$$q_{pcu} = 0.316\left(0.5+\frac{a}{b}\right)\sqrt{\frac{F_{cu}}{\gamma_c}}\quad (N/mm^2)$$

a

b

$a = 0.30\ m$, $b = 0.80\ m$

$$q_{pcu} = 0.316\left(0.5+\frac{0.30}{0.80}\right)\sqrt{\frac{30}{1.5}} = 1.236\ N/mm^2$$

$$q_{pcu} = 0.316 \sqrt{\frac{F_{cu}}{\gamma_c}} \quad (N/mm^2)$$

$$q_{pcu} = 0.316 \sqrt{\frac{30}{1.5}} = 1.41 \; N/mm^2$$

$$q_{pcu} = 1.60 \quad (N/mm^2)$$

نأخذ القيمه الاقل من الاربع قيم السابقه .

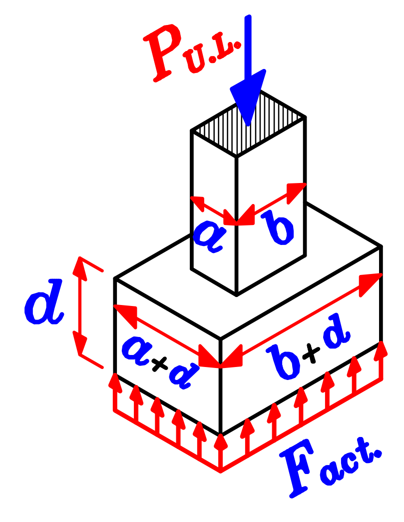
$$\therefore \; q_{pcu} = 1.236 \; N/mm^2$$

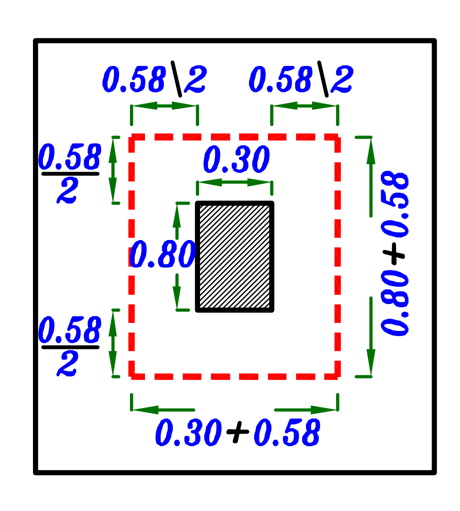
$$q_{pu} = 1.319 \; N/mm^2$$

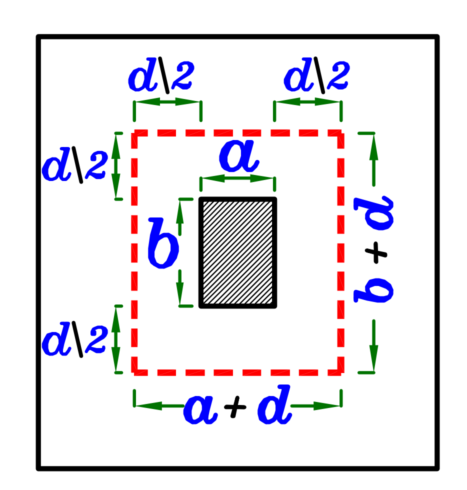
$q_{pu} > q_{pcu}$ ⟶ UnSafe punching shear. We have to increase dimensions.

Take $t_{R.C.} = 650 \; mm$ $\quad d = 580 \; mm$

Check Punching Shear again.







$$a + d = 0.30 + 0.58 = 0.88\ m$$

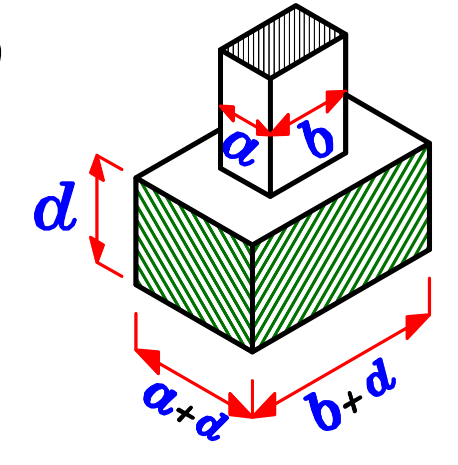
$$b + d = 0.80 + 0.58 = 1.38\ m$$

* Calculate Punching Force. (Q_p)

$$Q_p = P_{U.L.} - (F_{act.})\left[(a+d)(b+d)\right]$$

$$Q_p = 2850 - 240.7\left[0.88 * 1.38\right] = 2557.7\ kN$$

* Calculate Punching shear area. (A_p)



$$A_p = \left[2(a+d) + 2(b+d)\right] * d$$

$$A_p = \left[2(300 + 580) + 2(800 + 580)\right] * 580$$

$$A_p = 2621600\ mm^2$$

* Calculate Actual Punching shear stress. q_{pu}

$$q_{pu} = \frac{Q_p}{\left[2(a+d) + 2(b+d)\right] * d}$$

$$q_{pu} = \frac{2557.7 * 10^3}{2621600} = 0.975\ N/mm^2$$

* **Calculate allowable Punching shear stress.** q_{pcu}

$$b_o = 2(a+d)+2(b+d)$$

$$= 2(300+580)+2(800+580) = 4520 \text{ mm}$$

$$q_{pcu} = 0.8\left(\frac{\alpha\, d}{b_o} + 0.2\right)\sqrt{\frac{F_{cu}}{\gamma_c}}$$

$$q_{pcu} = 0.8\left(\frac{4*580}{4520} + 0.2\right)\sqrt{\frac{30}{1.5}} = 2.55 \text{ N/mm}^2$$

$$q_{pcu} = 0.316\left(0.5+\frac{a}{b}\right)\sqrt{\frac{F_{cu}}{\gamma_c}} \quad (\text{N/mm}^2)$$

$$q_{pcu} = 0.316\left(0.5+\frac{0.30}{0.80}\right)\sqrt{\frac{30}{1.5}} = 1.236 \text{ N/mm}^2$$

$$q_{pcu} = 0.316\sqrt{\frac{F_{cu}}{\gamma_c}} \quad (\text{N/mm}^2)$$

$$q_{pcu} = 0.316\sqrt{\frac{30}{1.5}} = 1.41 \text{ N/mm}^2$$

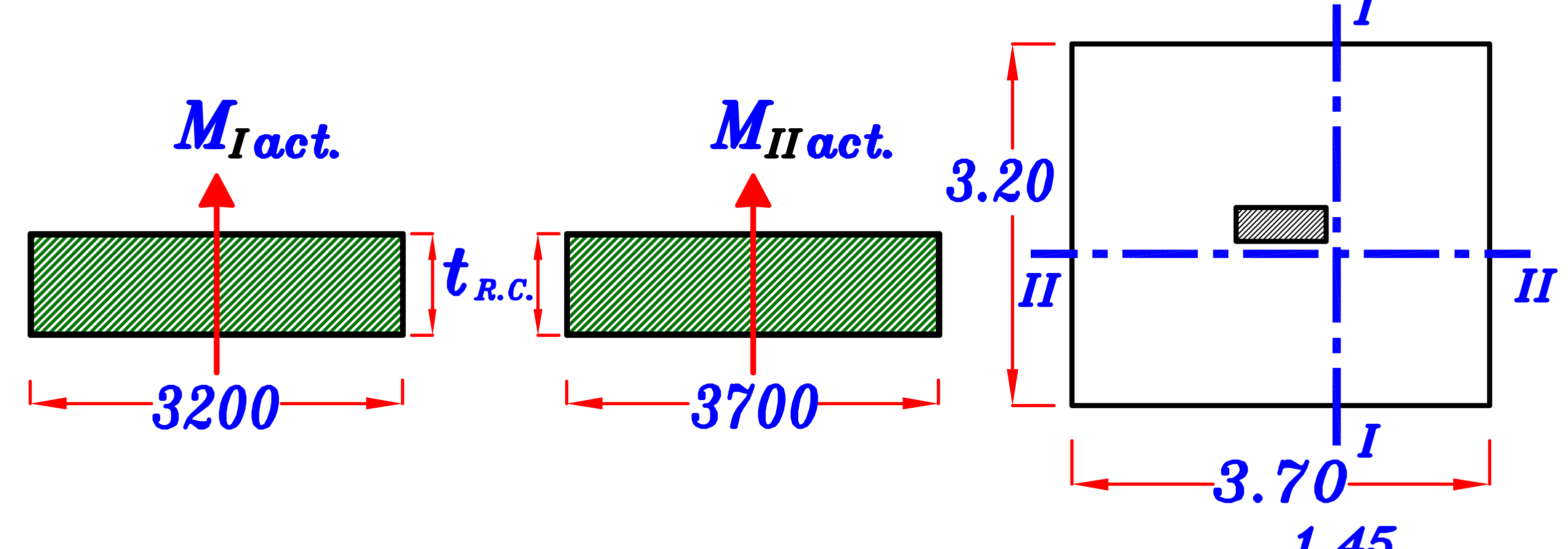
$$q_{pcu} = 1.60 \quad (\text{N/mm}^2)$$

نأخذ القيمة الاقل من الاربع قيم السابقه .

$$\therefore \quad q_{pcu} = 1.236 \text{ N/mm}^2 \qquad q_{pu} = 0.975 \text{ N/mm}^2$$

$q_{pu} \leqslant q_{pcu} \longrightarrow$ **Safe punching shear.**
No need to increase dimensions again.

5- Reinforcement of the Footing.



$$M_{I\,act.} = (F_{act.} * Z * B_{R.C.}) \frac{Z}{2}$$

$$= (240.7 * 1.45 * 3.20) \frac{1.45}{2}$$

$$= 809.7 \text{ kN.m}$$

1.45

0.725

3.20

3.70

$$J = 0.826$$

$$A_s = \frac{M_{I\,act.}}{J\,F_y\,d} = \frac{809.7 * 10^6}{0.826 * 400 * 580} = 4225.28 \text{ mm}^2$$

$$A_s\ (\text{mm}^2/\text{m}) = \frac{A_s}{B_{R.C.}} = \frac{4225.28}{3.20} = 1320.4 \text{ mm}^2/\text{m}'$$

Check $A_{s\,min}$

$$A_{s\,min} = \begin{cases} 1.5\,d = 1.5 * 580 = 870 \\ 5\,\phi\,12/\text{m}' = 565 \end{cases} \quad 870 \text{ mm}^2$$

$$\therefore A_s > A_{s\,min} \longrightarrow \text{o.k.}$$

$$A_s = 1320.0 \text{ mm}^2 \qquad \boxed{6\,\phi\,18/\text{m}'}$$

$$M_{II\,act.} = (F_{act.} * Z * L_{R.C.}) \frac{Z}{2}$$

$$= (240.7 * 1.45 * 3.70) \frac{1.45}{2}$$

$$= 936.2 \text{ kN.m}$$

$$J = 0.826$$

$$A_s = \frac{M_{II\,act.}}{J\,F_y\,d} = \frac{936.2 * 10^6}{0.826 * 400 * 580} = 4885.4 \text{ mm}^2$$

$$A_s\,(\text{mm}^2/\text{m}) = \frac{A_s}{B_{R.C.}} = \frac{4885.4}{3.70} = 1320.3 \text{ mm}^2/\text{m}'$$

Check $A_{s\,min}$

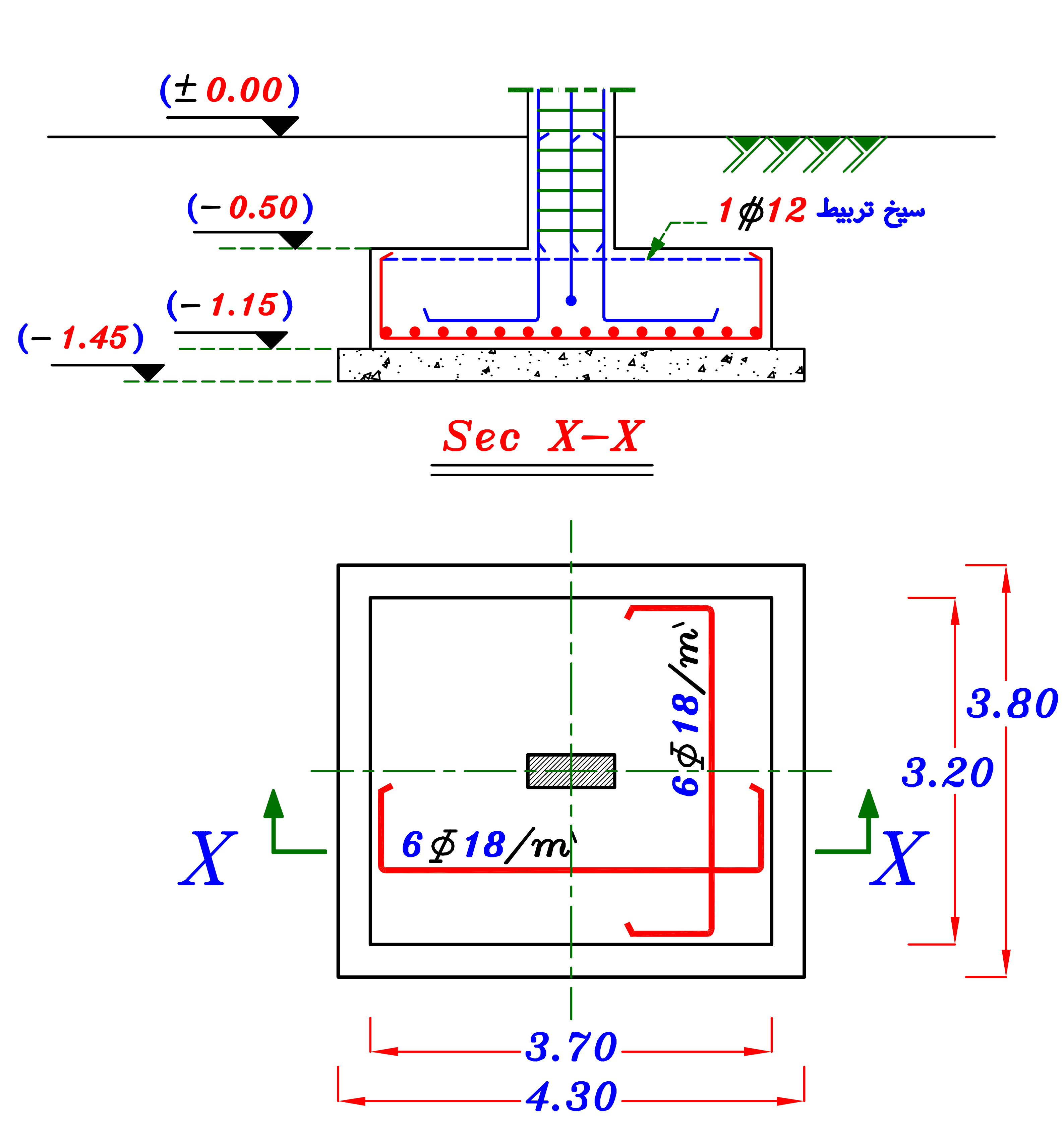
$$A_{s\,min} = \begin{cases} 1.5\,d = 1.5 * 580 = 870 \\ 5 \phi 12/\text{m}' = 565 \end{cases} \quad 870 \text{ mm}^2$$

$$\therefore A_s > A_{s\,min} \longrightarrow \text{o.k.}$$

$$A_s = 1320.3 \text{ mm}^2$$

$6 \phi 18/\text{m}'$

6- Details of Reinforcement.



Important Notes. ملاحظات هامه .

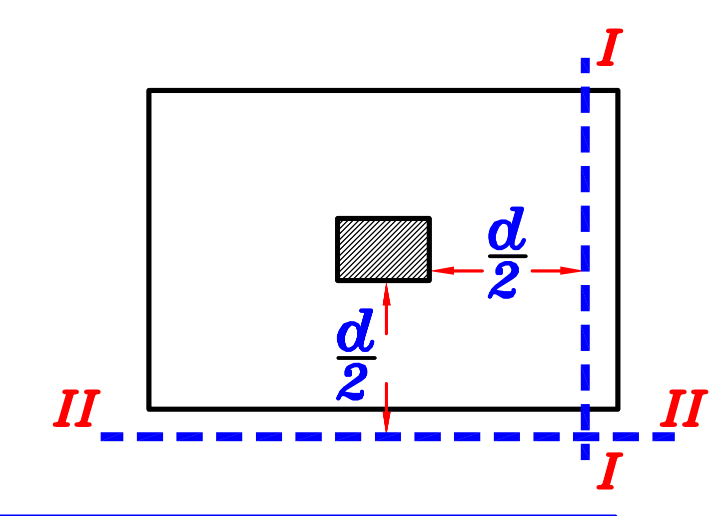
١ – فى حاله عمل check shear

و وقع مستوى ال critical section (الذى يبعد مسافه $\frac{d}{2}$ من وش العمود)

خارج القاعده المسلحه فانه لا يكون عليه أجهاد قص

$$Q_{SI} = q_u * l * 1.0\,m$$

$$Q_{SII} = Zero$$



٢ – فى حاله عمل check punching

و وقع مستوى ال critical section (الذى يبعد مسافه $\frac{d}{2}$ من وش العمود)

خارج القاعده المسلحه .

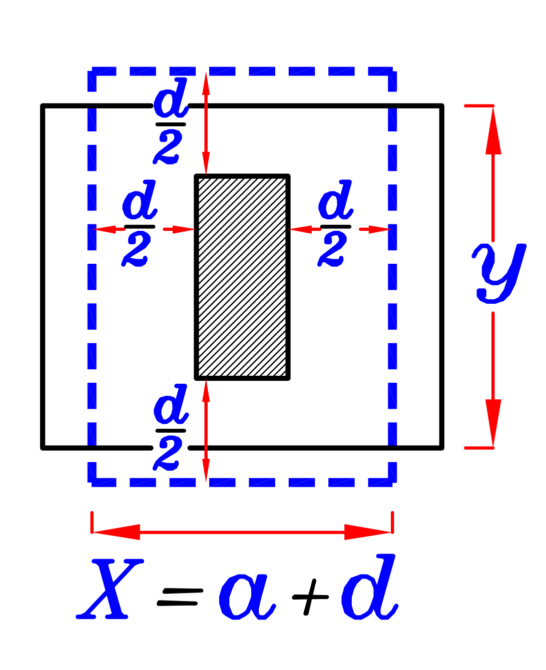
$$A_p = 2\,y * d$$

$$Q_p = P_{U.L.} - (F_{act.})\,[X * y]$$

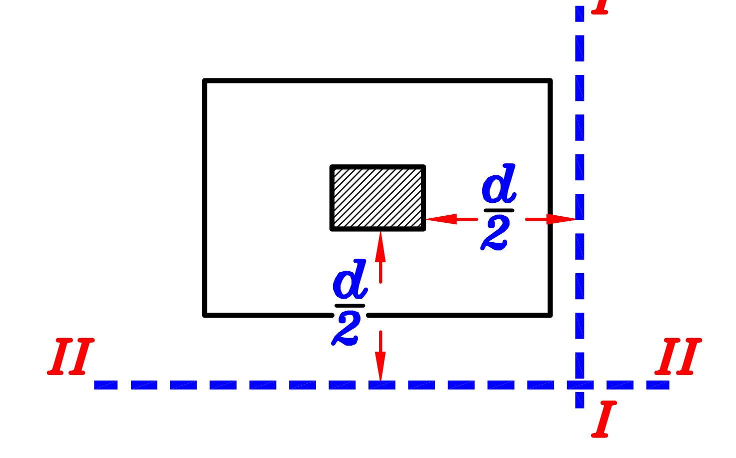
$$q_{pu} = \frac{Q_p}{2\,y * d}$$

الجانب y فقط هو الذى يحدث

عليه الانفصال عن القاعده

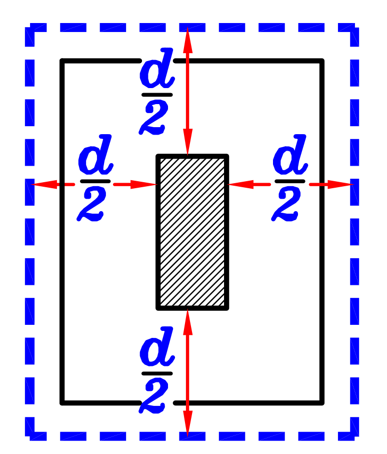


٣ ـ اذا وقعت كل مستويات ***check shear*** خارج القاعده المسلحه



No need to check shear

اذا وقعت كل مستويات ***check punching*** خارج القاعده المسلحه

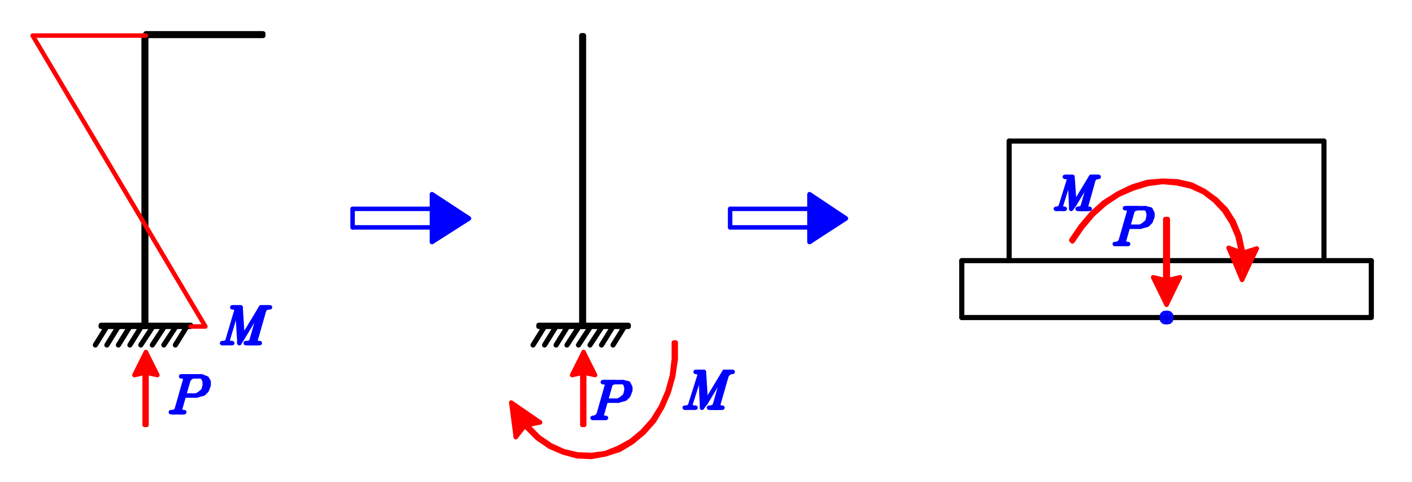


No need to check punching

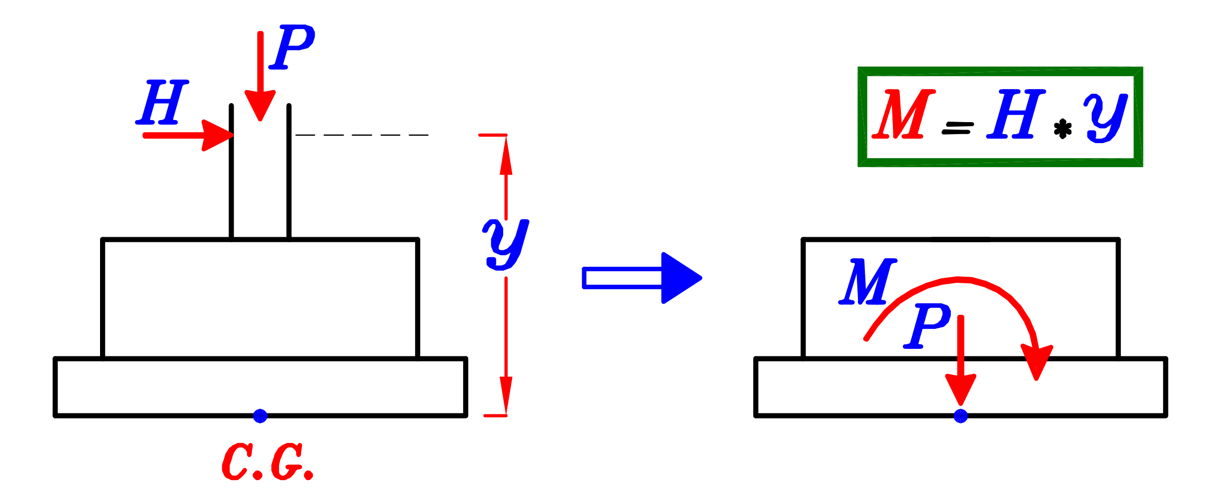
4 Design of Isolated Footing subjected to Moment and Normal M & P

تتولد عزوم على القواعد من أسباب عده منها :

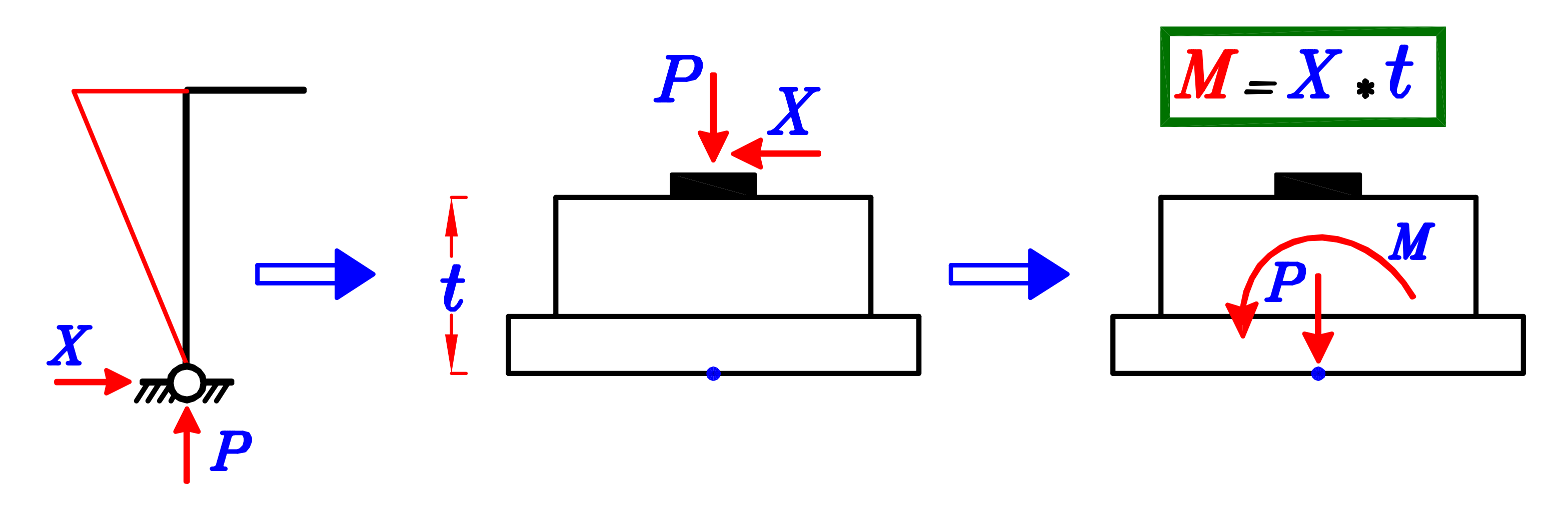
١- عزم صريح على العمود . (مثل الاعمده فى ال Fixed Frames) .



٢- وجود قوه أفقيه دائمه تؤثر على العمود على مسافه من C.G. القاعده .

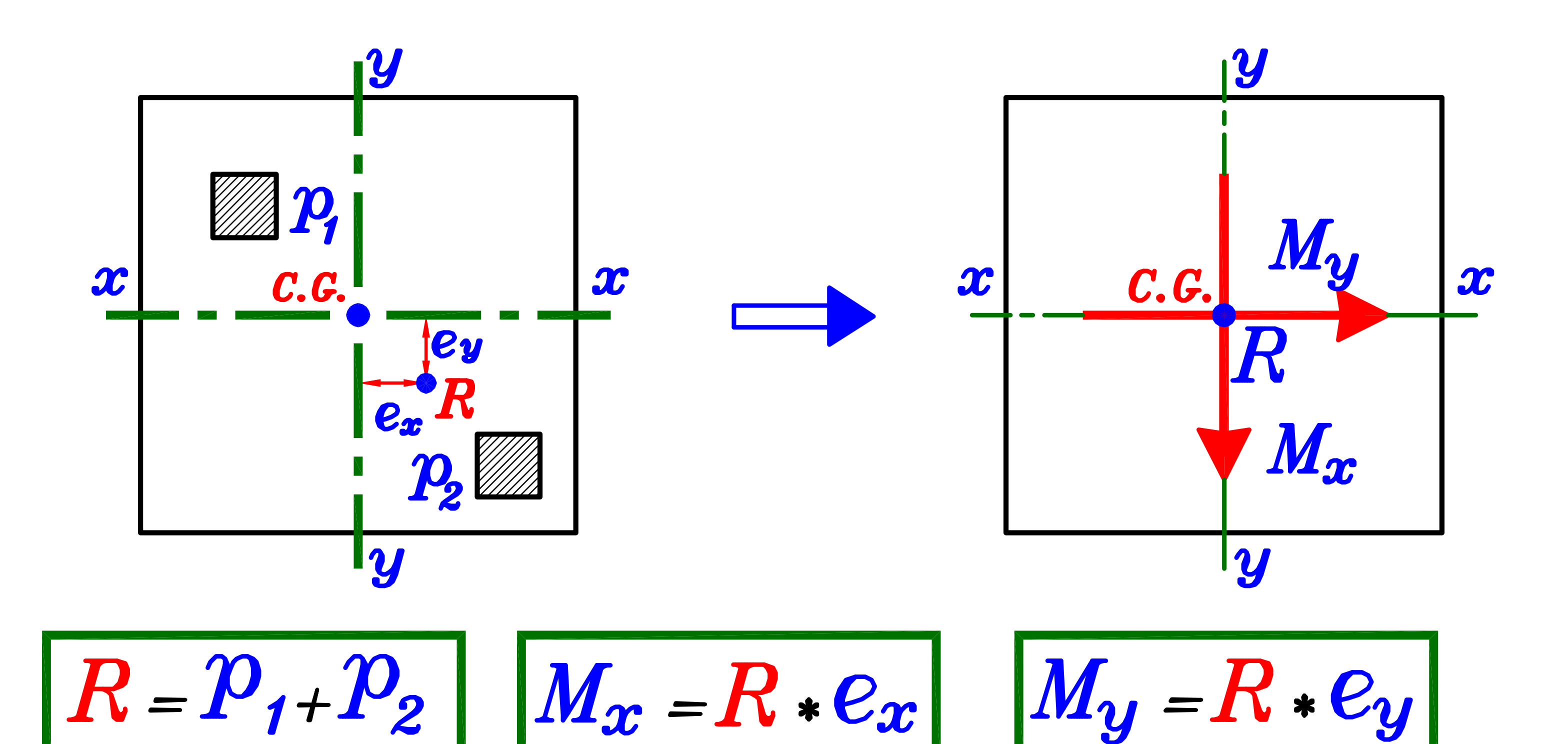


٣- و جود قاعده Hinged يوجد عليها رد فعل أفقى دائم قيمته X



٤ ـ ال C.M. للاحمال (أى مركز الاحمال Center of Mass)

لا ينطبق على C.G. للقاعده فيسبب eccentricity مما يسبب عزوم دائمه .



$$R = P_1 + P_2$$

$$M_x = R * e_x$$

$$M_y = R * e_y$$

Types of moments on Footings.

أنواع العزوم التى من الممكن أن تؤثر على القواعد .

1 – Permanent Moment. العزوم الدائمه .

و هى العزوم الناتجه عن الاحمال الدائمه مثل *Gravity loads* & *Dead loads*

و هى عزوم تكون ثابته المقدار و الاتجاه .

و يفضل إلغائها عن طريق ترحيل القاعده مسافه *e* عكس اتجاه الـ *moment* .

2– Temporary Moment. العزوم المتغيره أو الغير دائمه .

و هى العزوم الناتجه عن الاحمال المتغيره مثل

L.L. , *Wind load* & *Earthquake loads.*

و هى عزوم متغيره الاتجاه ↷ *or* ↶ و لكن بقيمه ثابته .

و يتم تصميم القاعده بحيث يكون الاجهاد أسفل القاعده يساوى :-

$$F_{act} = \frac{P}{A} \pm \frac{M\,y}{I}$$

1- Design of isolated Footings subjected to permanent moment.

تصميم القواعد المنفصله المعرضه لعزوم ثابته المقدار و الاتجاه .

يفضل ترحيل القاعده مسافه e عكس اتجاه ال moment و ذلك لإلغاء ال moment .

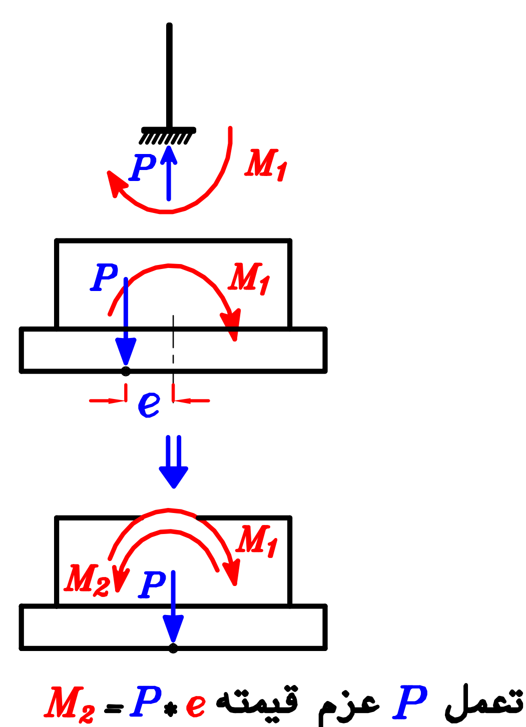
ترحيل القواعد

قيمه (Normal stress) على التربه تحسب من المعادله التاليه

$$F = -\frac{P}{A} \pm \frac{My}{I}$$

و من المفضل عدم عمل شد (Tension) على التربه .





تعمل P عزم قيمته $M_2 = P * e$

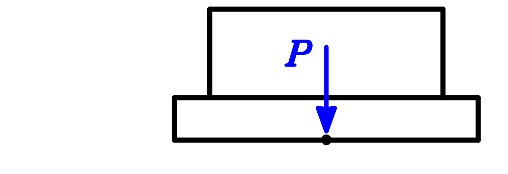
معاكس لـ M_1 اذا أخذنا قيمه لـ e

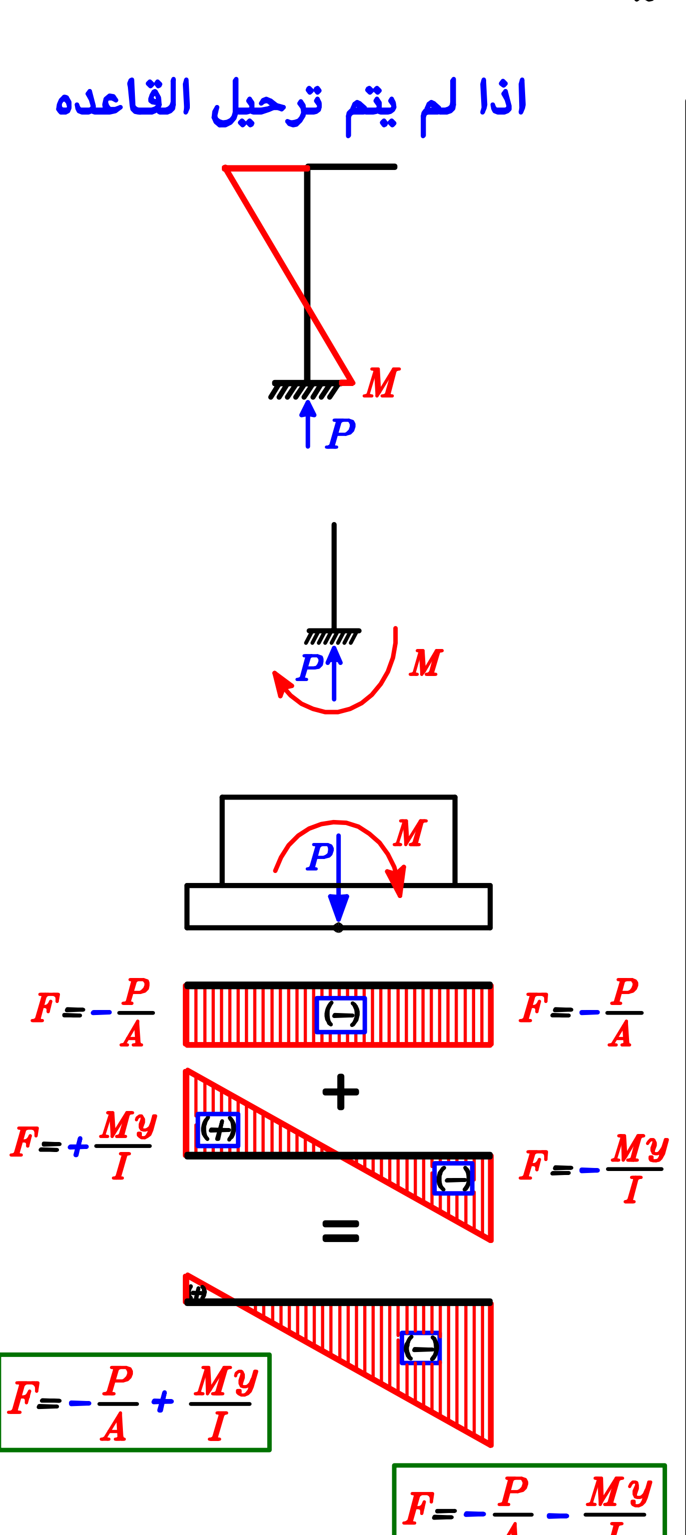
بحيث تكون $M_2 = M_1$ فلن يكون هناك عزم

و تكون قوى ضغط فقط

و تكون قيمه $F = -\frac{P}{A}$ (Normal stress)

فنضمن أن ال stress كله compression



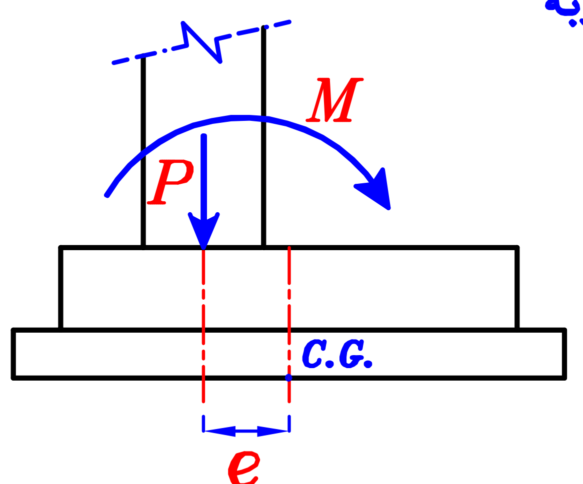


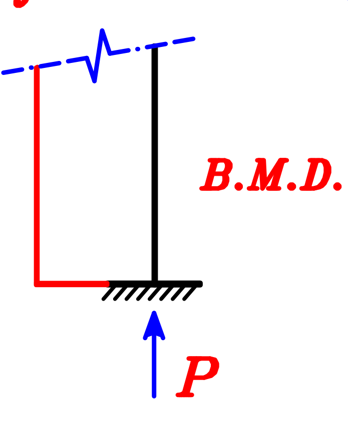
العزم من اتجاه واحد فقط.

أ ـ القاعده التى يوجد عليها **Reactions** فى إتجاه P و M معاً

ترحل القاعده عكس إتجاه الـ **Moment** فى رسمة الـ **B.M.D.** مسافة (e)

لعمل **stress uniform** على التربه





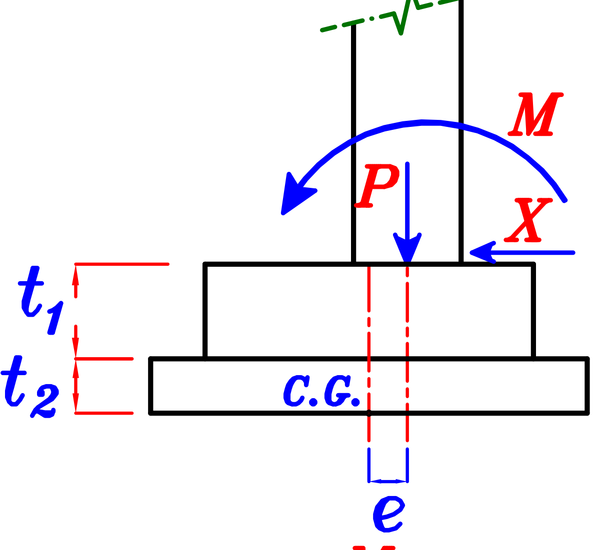
$$\because \sum M_{C.G.} = Zero \quad \therefore M - P(e) = Zero$$

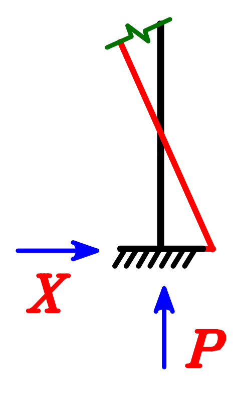
$$e = \frac{M}{P}$$

ب ـ القاعده التى يوجد عليها **Reactions** فى إتجاه X و P و M معاً

ترحل القاعده عكس اتجاه الـ **Moment** فى رسمة الـ **B.M.D.** مسافه (e)

لعمل **stress uniform** على التربه





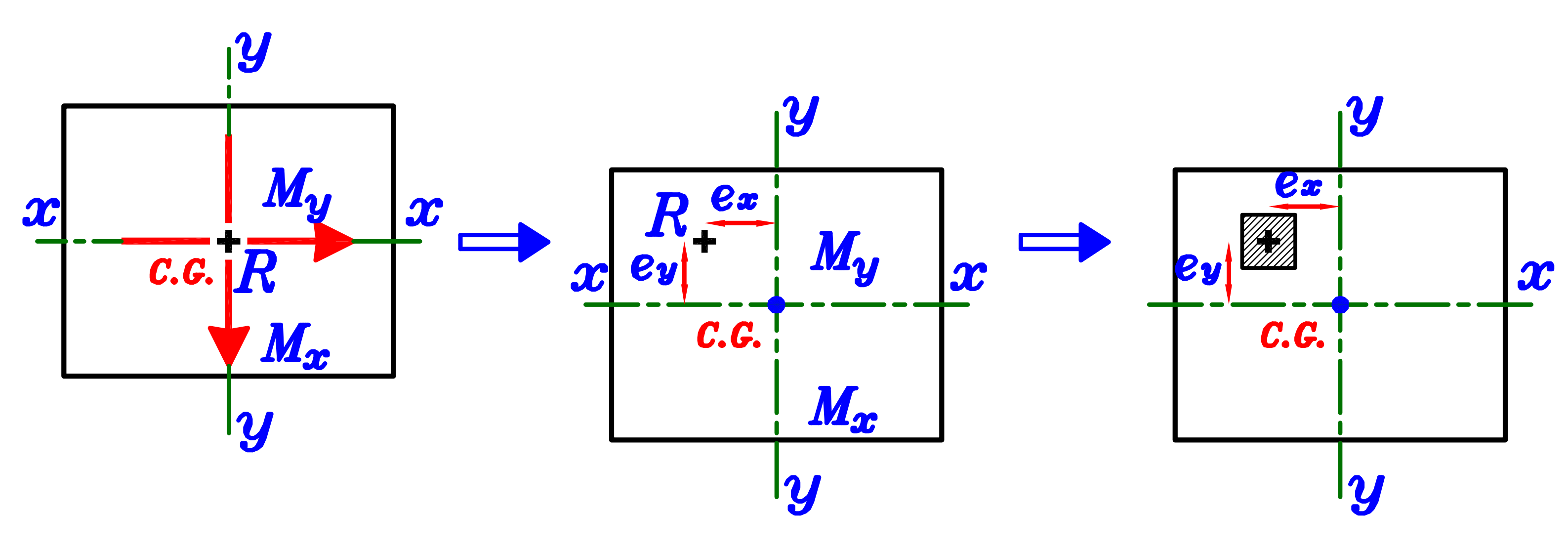
$$\because \sum M_{C.G.} = Zero$$

$$\therefore X(t_1+t_2) + M - P(e) = Zero \quad \therefore$$

$$e = \frac{X(t_1+t_2)+M}{P}$$

العزم من الاتجاهين .

يتم ترحيل القاعده عكس الـ *Moment* فى الاتجاهين e_y & e_x



ملحوظه هامه يتم ترحيل القاعده و ليس ترحيل العمود .

ملحوظه هامه

يتم ترحيل القاعده عكس اتجاه الـ *Moment* أى جهه رأس السهم .

حتى تكون محصله الـ *Moment* النهائيه عند *C.G.* القاعده يساوى صفر .

$$e_x = \frac{M_x}{P}$$

$$e_y = \frac{M_y}{P}$$

$$M_{at\ C.G.\ of\ the\ Footing} = Zero$$

ثم يتم تصميم القاعده على P فقط.

Example.

It is required to design a rectangular Footing to Support a R.C column of thickness (40 * 70) cm.
The column working load is 1500 kN

and permanent moment ↑ $M_x = 450$ kN.m

and permanent moment → $M_y = 600$ kN.m

450 kN.m
1500 kN
600 kN.m
0.40
0.70

The allowable net bearing capacity in the Footing site is 150 kN/m². ($F_{cu} = 25$ N/mm², $F_y = 360$ N/mm²).
and draw details of RFT. to scale 1:50

Solution.

Data given. Column dimensions (400 * 700) mm

$P_{col.}$ (working) = 1500 kN $\quad$ $P_{col.}$ (U.L.) = 1500 * 1.5 = 2250 kN

$M_x = 450$ kN.m $\quad$ $M_y = 600$ kN.m

Bearing capacity of the soil = $q_{all} = 150$ kN/m²

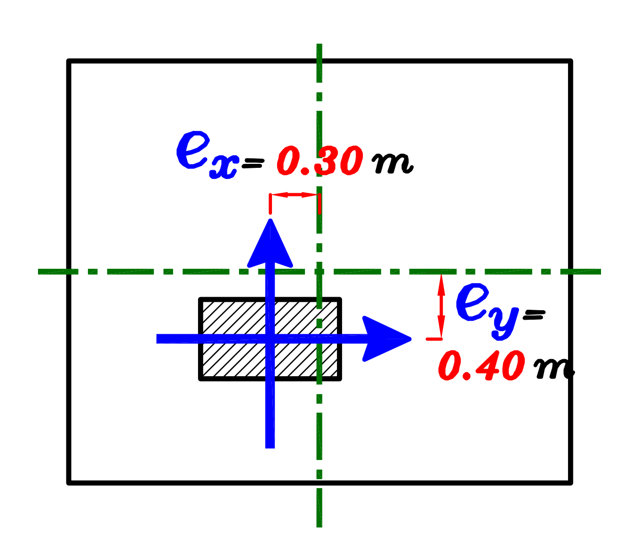
$F_{cu} = 25$ N/mm² $\quad$ $F_y = 360$ N/mm²

لان العزوم permanent moment
ممكن لالغاء تأثير العزوم على القاعده يتم ترحيل القاعده عكس العزوم

$$e_x = \frac{M_x}{P} = \frac{450}{1500} = 0.30 \text{ m}$$

$$e_y = \frac{M_y}{P} = \frac{600}{1500} = 0.40 \text{ m}$$

عند ترحيل القاعده عكس ال moment
سيتم الغاء تأثير ال moment
و بالتالى يكون ال stresses على التربه متساوى
أى يكون على التربه uniform stresses
ثم يتم تصميم القاعده بالطريقه السابقه .



1– Calculate the Footing area (Width & Length of R.C. Footing.)

Choose $t_{P.C.} = 30\ cm > 20\ cm$

$$L_{P.C.} - B_{P.C.} = b - a = 0.70 - 0.40 = 0.30\ m$$

$$L_{P.C.} = B_{P.C.} + 0.30\ m \quad \text{------(1)}$$

$$A_{P.C.} = \frac{P_w}{q_{all}} = \frac{1500\ (kN)}{150\ (kN/m^2)} = 10.0\ m^2$$

$$A_{P.C.} = B_{P.C.} * L_{P.C.} = 10.0\ m^2 \quad \text{-----(2)}$$

$$B_{P.C.} * L_{P.C.} = B_{P.C.} * (B_{P.C.} + 0.30) = 10.0\ m^2$$

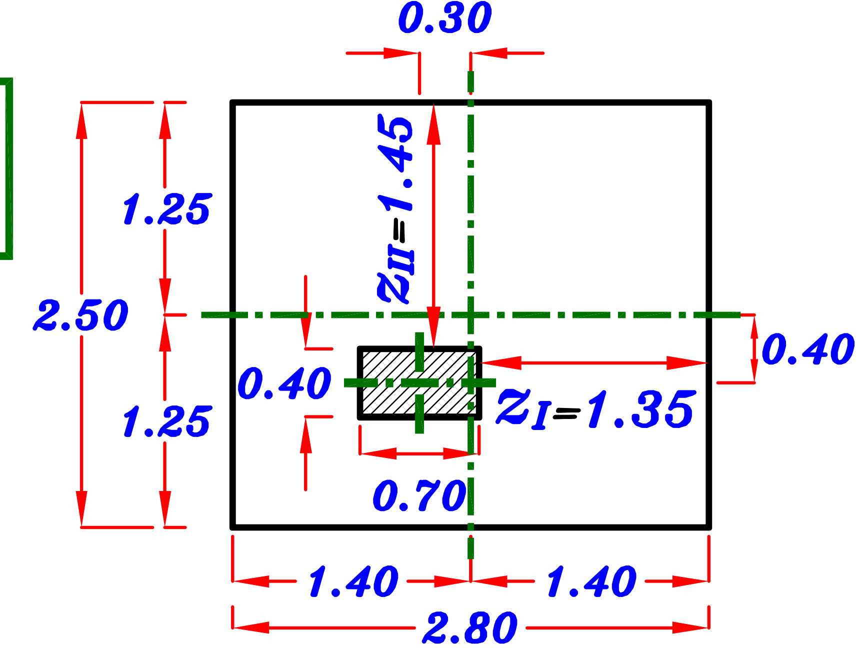
$$B_{P.C.} = 3.01\ m$$

$B_{P.C.} = 3.10\ m$ | $L_{P.C.} = 3.40\ m$

$B_{R.C.} = 2.50\ m$ | $L_{R.C.} = 2.80\ m$

$$Z_I = 2.8 - 1.4 + 0.3 - 0.35 = 1.35\ m$$

$$Z_{II} = 2.5 - 1.25 + 0.4 - 0.2 = 1.45\ m$$



2- Design the critical sections For moment. (Depth of R.C. Footing.)

- Actual Normal stress on R.C. Footing (U.L.)

$$F_{act.} = \frac{P_{U.L.}}{B_{R.C.} * L_{R.C.}} = \frac{2250}{2.50 * 2.80} = 321.4\ kN/m^2$$

Direction I

$$Z_I = \frac{2.80}{2} + 0.30 - \frac{0.70}{2} = 1.35\ m$$

Force = Stress * Area

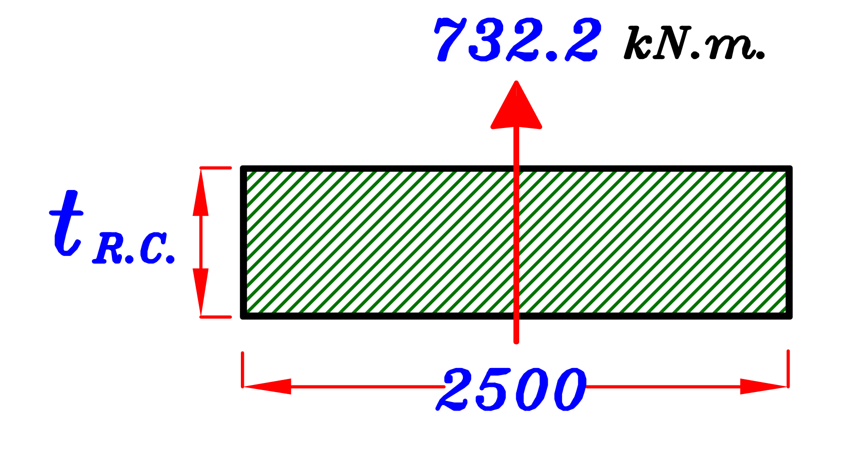
$$Force = F_{act.} * Z_I * B_{R.C.}$$

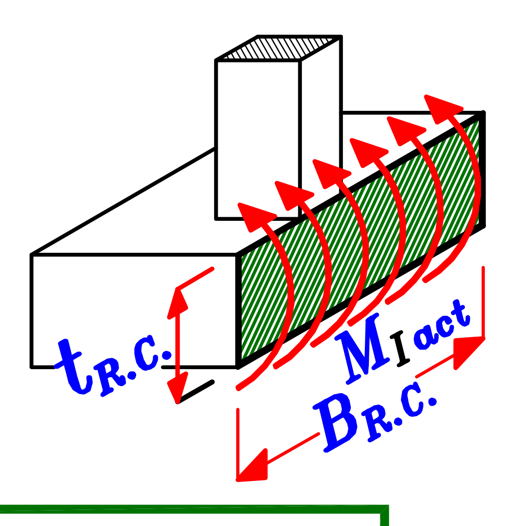
$$= 321.4 * 1.35 * 2.50 = 1084.7\ kN$$

moment = Force * Distance

$$M_{I\,act.} = (F_{act.} * Z_I * B_{R.C.})\ \frac{Z_I}{2}$$

$$= (321.4 * 1.35 * 2.50)\ \frac{1.35}{2} = 732.2\ kN.m$$



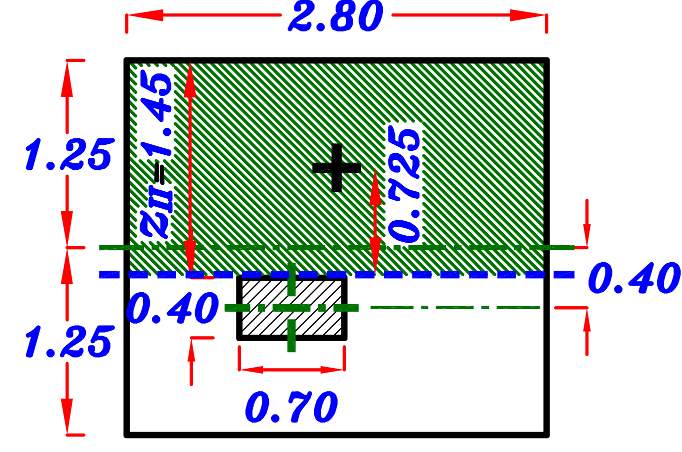


$$\because\ d_I = C_1 \sqrt{\frac{M_{I\,act.}}{F_{cu} * b}}$$

Choose $C_1 = 5.0$

$$\therefore\ d_I = 5.0 \sqrt{\frac{732.2 * 10^6}{25 * 2500}} = 541.2\ mm$$

Direction II



$$Z_{II} = \frac{2.50}{2} + 0.40 - \frac{0.40}{2} = 1.45\ m$$

$$Force = Stress * Area$$

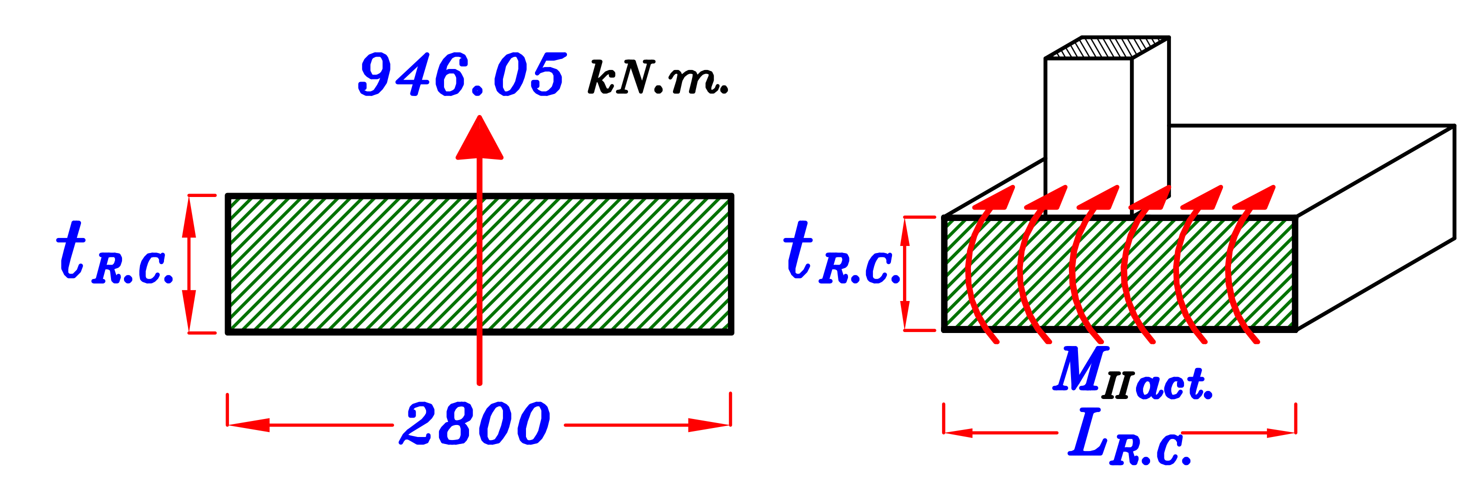
$$Force = F_{act.} * Z_{II} * B_{R.C.}$$

$$= 321.4 * 1.45 * 2.80 = 1304.9\ kN$$

$$moment = Force * Distance$$

$$M_{II\,act.} = \left(F_{act.} * Z_{II} * B_{R.C.}\right) \frac{Z_{II}}{2}$$

$$= \left(321.4 * 1.45 * 2.80\right) \frac{1.45}{2} = 946.05\ kN.m$$



$$\because\ d_{II} = C_1 \sqrt{\frac{M_{II act.}}{F_{cu} * b}}$$ Choose $C_1 = 5.0$

$$\therefore\ d_{II} = 5.0 \sqrt{\frac{946.05 * 10^6}{25 * 2800}} = 581.2\ mm$$

Take d The bigger of d_I & d_{II} $= 581.2\ mm$

$$t_{R.C.} = d + 70\ mm = 581.2 + 70 = 651.2\ mm$$

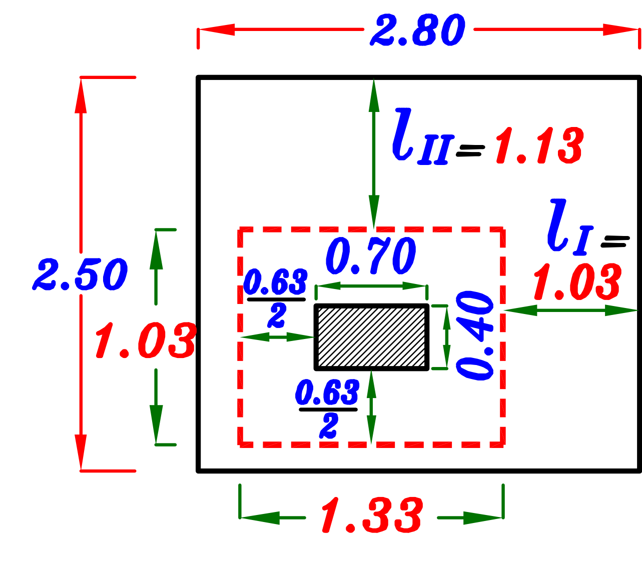
$t_{R.C.} = 700\ mm$

$d = 630\ mm$

3 – Check Shear.

$a + d = 0.40 + 0.63 = 1.03$ m

$b + d = 0.70 + 0.63 = 1.33$ m

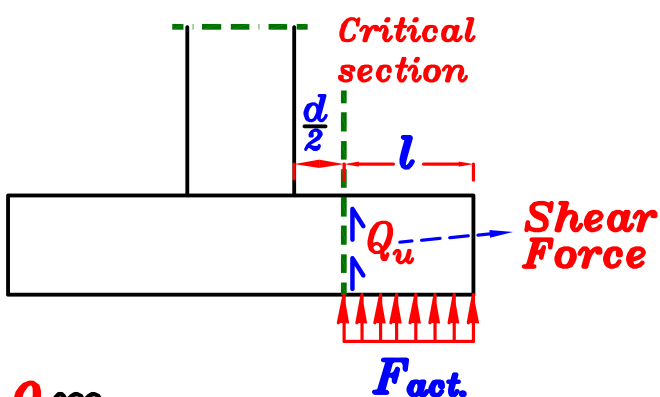




*** Critical section For Shear.**

Take l The bigger of l_I & l_{II}

$$l = 1.13 \text{ mm}$$



*** Actual shear Force. (Q_u) For 1.0 m**

$$Q_u = F_{act.} * l * 1.0\,m = 321.4 * 1.13 * 1.0\,m = 363.2 \text{ kN}$$

*** Calculate Actual shear stress. (q_u)**

$$q_u = \frac{Q_u}{b * d} = \frac{363.2 * 10^3}{1000 * 630} = 0.576 \text{ N/mm}^2$$

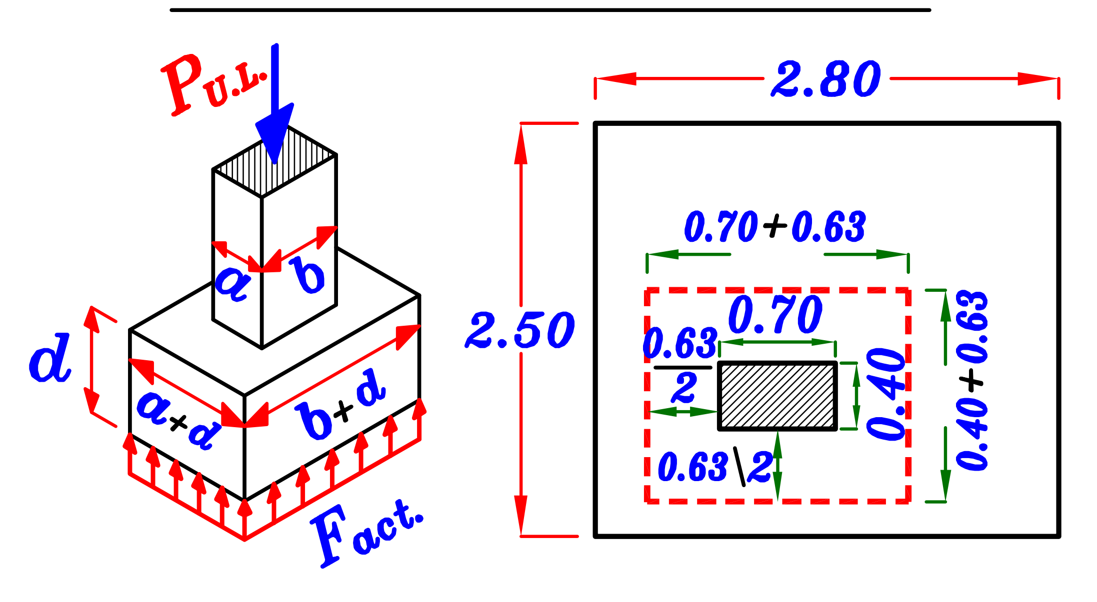
*** Allowable shear stress. (q_{su})**

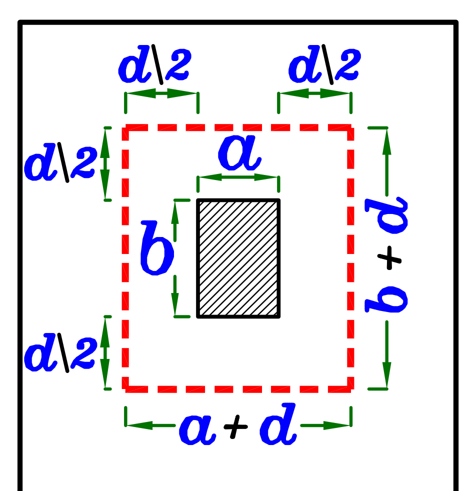
$$q_{su} = 0.16 \sqrt{\frac{F_{cu}}{\gamma_c}} = 0.16 \sqrt{\frac{25}{1.5}} = 0.653 \text{ N/mm}^2$$

$$q_u < q_{su}$$ ⟶ Safe shear stresses

No need to increase dimensions.

4- Check Punching Shear.





$$a + d = 0.40 + 0.63 = 1.03\ m$$

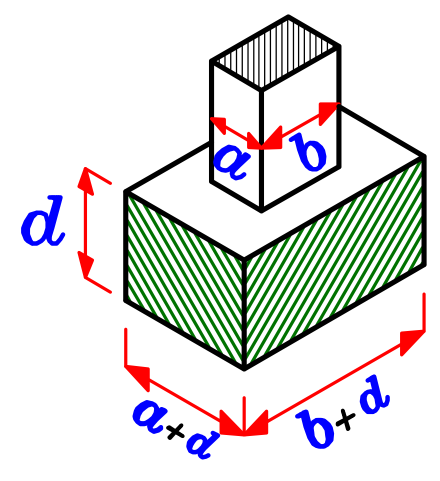
$$b + d = 0.70 + 0.63 = 1.33\ m$$

* **Calculate Punching Force.** (Q_p)

$$Q_p = P_{U.L.} - (F_{act.}) \left[(a+d)(b+d)\right]$$

$$Q_p = 2250 - 321.4 \left[1.03 * 1.33\right] = 1809.7\ kN$$

* **Calculate Punching shear area.** (A_p)



$$A_p = \left[2(a+d) + 2(b+d)\right] * d$$

$$A_p = \left[2(400+630) + 2(700+630)\right] * 630$$

$$A_p = 2973600\ mm^2$$

* Calculate Actual Punching shear stress. q_{pu}

$$q_{pu} = \frac{Q_p}{[2(a+d)+2(b+d)]*d}$$

$$q_{pu} = \frac{1809.7*10^3}{2973600} = 0.608 \ N/mm^2$$

* Calculate allowable Punching shear stress. $q_{p_{cu}}$

نأخذ القيمه الاقل من الاربع قيم التاليه .

$$q_{pcu} = 0.8\left(\frac{\alpha\, d}{b_o} + 0.2\right)\sqrt{\frac{F_{cu}}{\gamma_c}}$$

$\alpha = 4$ Interior Col.

$$b_o = 2(a+d)+2(b+d) = 2(400+630)+2(700+630) = 4720 \ mm$$

$$q_{pcu} = 0.8\left(\frac{4*630}{4720} + 0.2\right)\sqrt{\frac{25}{1.5}} = 2.39 \ N/mm^2$$

$$q_{pcu} = 0.316\left(0.5+\frac{a}{b}\right)\sqrt{\frac{F_{cu}}{\gamma_c}} \quad (N/mm^2)$$

a, b

$a = 0.40\ m$, $b = 0.70\ m$

$$q_{pcu} = 0.316\left(0.5+\frac{0.40}{0.70}\right)\sqrt{\frac{25}{1.5}} = 1.38 \ N/mm^2$$

$$q_{pcu} = 0.316\sqrt{\frac{F_{cu}}{\gamma_c}} = 0.316\sqrt{\frac{25}{1.5}} = 1.29 \ N/mm^2$$

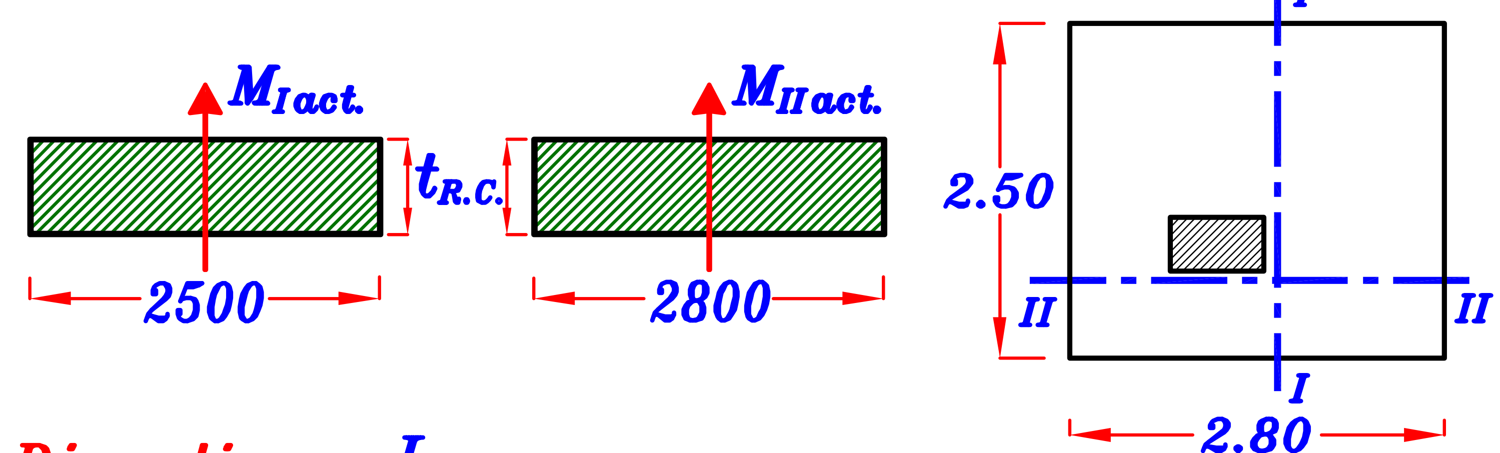
$$q_{pcu} = 1.60 \quad (N/mm^2)$$

$\therefore$ $q_{pcu} = 1.29 \ N/mm^2$ نأخذ القيمه الاقل من الاربع قيم السابقه .

$q_{pu} = 0.608 \ N/mm^2$

$q_{pu} \leqslant q_{p_{cu}} \longrightarrow$ Safe punching shear. No need to increase dimensions.

5- Reinforcement of the Footing.



Direction I

$$M_{I\,act.} = (F_{act.} * Z_I * B_{R.C.})\ \frac{Z_I}{2}$$

$$= (321.4 * 1.35 * 2.50)\ \frac{1.35}{2}$$

$$= 732.2 \ kN.m$$

$Z_I = 1.35$

2.50

0.675

2.80

$$J = 0.826$$

$$A_s = \frac{M_{I\,act.}}{J\ F_y\ d} = \frac{732.2 * 10^6}{0.826 * 360 * 630} = 3908.5 \ mm^2$$

$$A_{s\ (mm^2/m)} = \frac{A_s}{B_{R.C.}} = \frac{3908.5}{2.50} = 1563.4 \ mm^2/m'$$

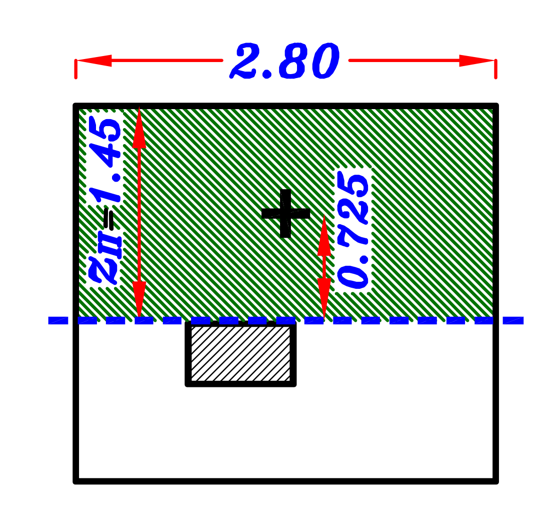
Check $A_{s\,min}$

$$A_{s\,min} = \begin{cases} 1.5\,d = 1.5 * 630 = 945 \\ 5\,\phi\,12/m' = 565 \end{cases} \ 945 \ mm^2$$

$$\therefore A_s > A_{s\,min} \longrightarrow o.k.$$

$$A_s = 1563.4 \ mm^2 \qquad \boxed{7\,\phi\,18/m'}$$

Direction II



$$M_{II\,act.} = (F_{act.} * z_{II} * B_{R.C.})\ \frac{z_{II}}{2}$$

$$= (321.4 * 1.45 * 2.80)\ \frac{1.45}{2}$$

$$= 946.05 \text{ kN.m}$$

$$J = 0.826$$

$$A_s = \frac{M_{II\,act.}}{J\ F_y\ d} = \frac{946.05 * 10^6}{0.826 * 360 * 630} = 5050 \text{ mm}^2$$

$$A_s\ (mm^2/m) = \frac{A_s}{B_{R.C.}} = \frac{5050}{2.80} = 1803.6 \text{ mm}^2/m`$$

Check $A_{s\,min}$

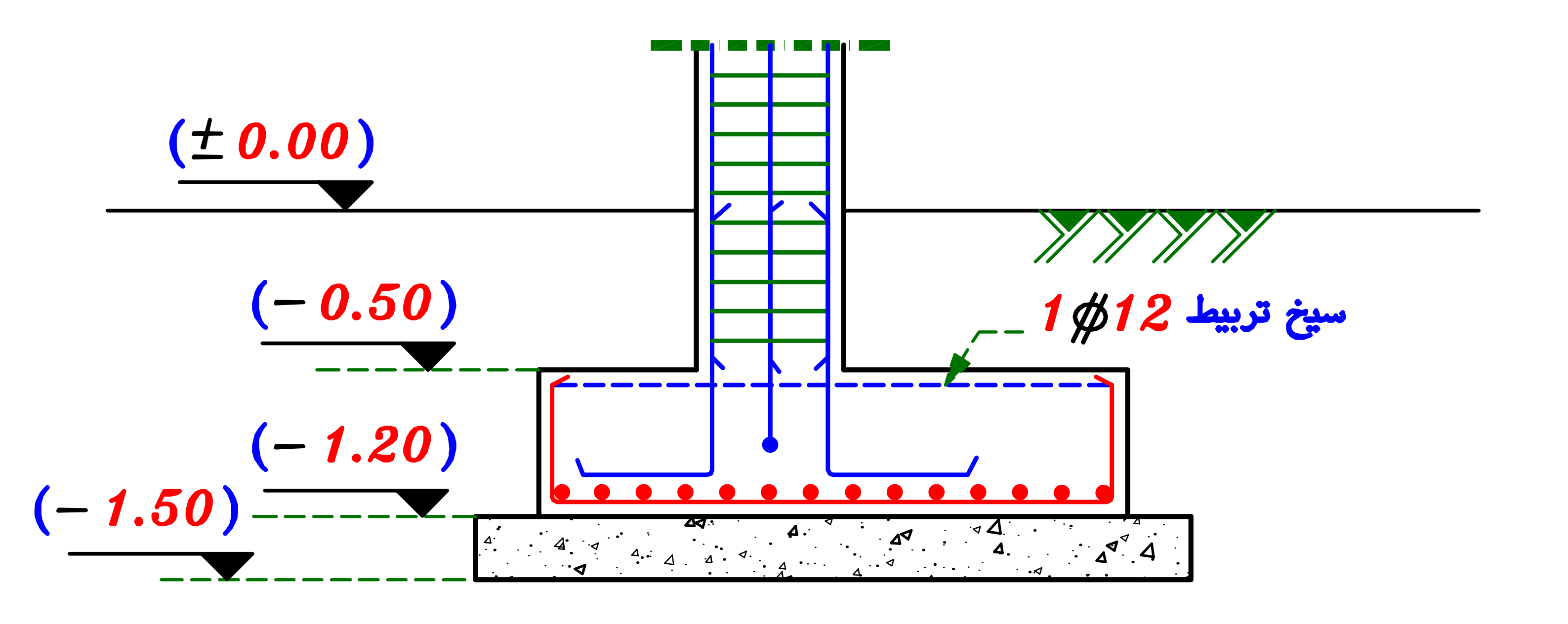
$$A_{s\,min} = \begin{cases} 1.5\,d = 1.5 * 630 = 945 \\ 5\,\phi\,12/m` = 565.5 \end{cases}\ 945 \text{ mm}^2$$

$$\therefore\ A_s > A_{s\,min} \longrightarrow \text{o.k.}$$

$$A_s = 1803.6 \text{ mm}^2$$

8 ϕ 18/m`

6- Details of Reinforcement.



0.3 1.10 1.70 0.3

0.3

0.30

8 ϕ18/m\`

1.65

3.10

2.50

0.40

7 ϕ18/m\`

0.85

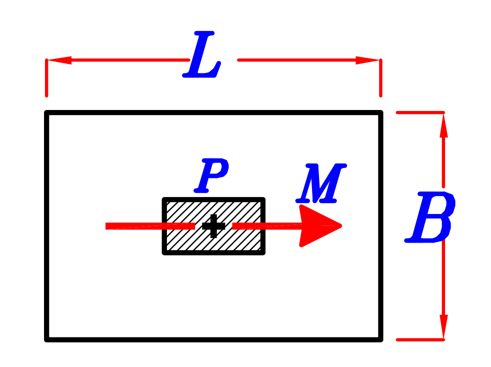
0.3

2.80

3.40

2 - Design of isolated Footings subjected to temporary moment.

تصميم القواعد المنفصله المعرضه لعزوم متغيره أو غير دائمه .

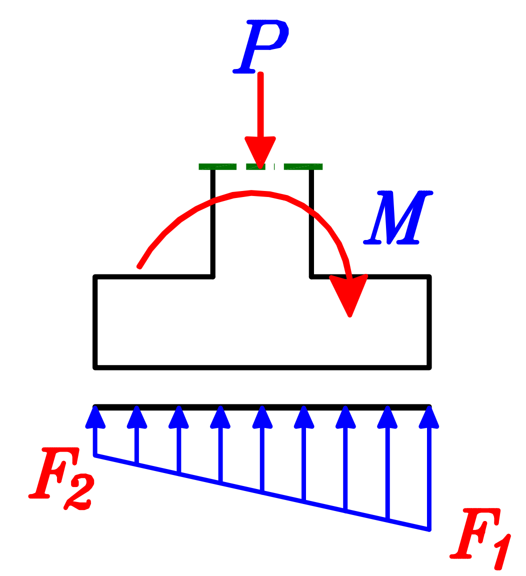


العزوم الناتجه عن الاحمال المتغيره مثل

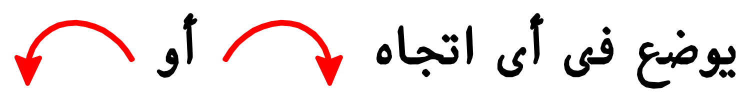
L.L. , Wind load

& Earthquake loads.

Case of single moment.



فى حاله وجود عزم واحد *variable* على القاعده

يوضع فى أى اتجاه  أو

و يفضل وضع أبعاد القاعده بحيث يكون

العرض الكبير للقاعده موازى لاتجاه الـ *moment*

و يؤخذ تأثير العزم عند حساب الاجهادات على التربه .

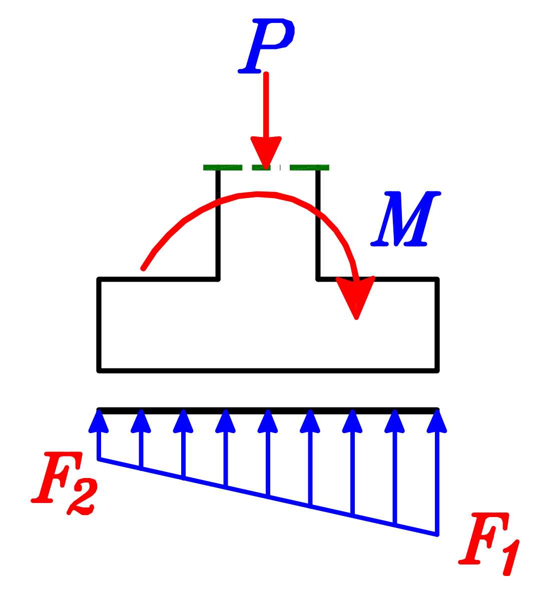
$$F_1 = \frac{P}{A} + \frac{My}{I}$$

$$F_2 = \frac{P}{A} - \frac{My}{I}$$

$(+Ve) \longrightarrow$ Compression stress.

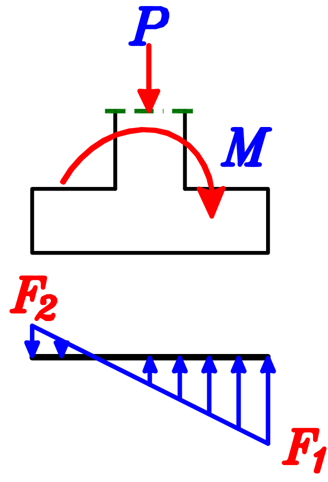
$(-Ve) \longrightarrow$ Tension stress.

و يتم اختيار أبعاد القاعده B , L



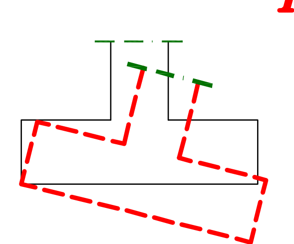
لتحقيق الشروط التاليه :

1. $F_1 \leq$ Allowable bearing capacity q_{all}



2. $F_2 > Zero$ لكى لا يوجد شد على التربه

No Tension on soil.



3. $F_2 \simeq \frac{F_1}{2}$ يفضل

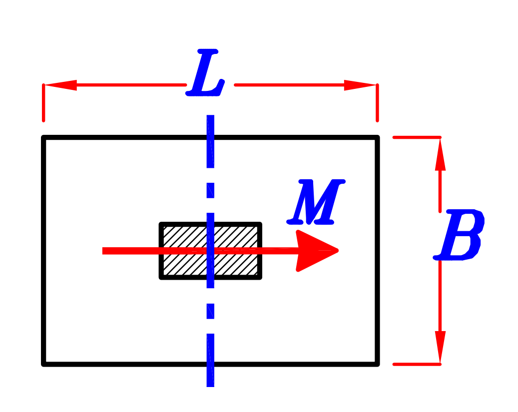
لكى نضمن عدم دوران القاعده

to avoid tilting of the Footing.

4. $L - B = b - a$ مع محاوله الحفاظ على الشرط

Steps of design Footing subjected to M , P

For rectangular Footing.



و يفضل وضع أبعاد القاعده بحيث يكون

العرض الكبير للقاعده موازى لاتجاه ال moment

Area of the Footing = $A = B * L$

Moment of Inertia For the Footing = $I = \frac{B * L^3}{12}$

Stresses on soil.

$$\therefore \quad F = \frac{P}{A} \pm \frac{M\,y}{I}$$

$A = B * L$ $\qquad$ $I = \frac{B * L^3}{12}$ $\qquad$ $y = \frac{L}{2}$

عند طرف القاعده

$$\therefore \quad F = \frac{P}{B * L} \pm \frac{M * L \backslash 2}{B * L^3 \backslash 12}$$

$$\therefore \quad F = \frac{P}{B * L} \pm \frac{6\,M}{B * L^2}$$

عند طرف القاعده

1 – Calculate the Footing area. (Width & Length of R.C. Footing.)

IF $t_{P.C.} \geq 20\ cm$

get $B_{P.C.}$, $L_{P.C.}$ From

$$L_{P.C.} - B_{P.C.} = b - a \quad \text{------} (1) \quad B_{P.C.} , L_{P.C.}$$

Actual Normal stress on soil = Bearing Capacity of soil.

$$F_1 = \frac{N}{B_{P.C.} * L_{P.C.}} + \frac{6\,M}{B_{P.C.} * L_{P.C.}^2} = q_{all} \quad \text{---} (2) \quad B_{P.C.} , L_{P.C.}$$

يتم حل معادلتين فى مجهولين و تحديد قيمه كلا من $B_{P.C.}$, $L_{P.C.}$

بعد حساب $B_{P.C.}$ & $L_{P.C.}$ يقربا لاقرب ٥٠ مم بالزياده

$$B_{R.C.} = B_{P.C.} - 2\,t_{P.C.}$$

$$L_{R.C.} = L_{P.C.} - 2\,t_{P.C.}$$

Check .

$$F_2 = \frac{N}{B_{P.C.} * L_{P.C.}} - \frac{6\,M}{B_{P.C.} * L_{P.C.}^2} > Zero$$

حتى لا يكون هناك tension على التربه .

IF $F_2 < Zero$ ⟶ أى tension على التربه .

Increase $B_{P.C.}$, $L_{P.C.}$

IF $t_{P.C.} < 20\ cm$

get $B_{R.C.}$, $L_{R.C.}$ From

$$L_{R.C.} - B_{R.C.} = b - a \quad \text{------} (1) \quad B_{R.C.} , L_{R.C.}$$

Actual Normal stress on soil = Bearing Capacity of soil.

$$F_1 = \frac{N}{B_{R.C.} * L_{R.C.}} + \frac{6M}{B_{R.C.} * L^2_{P.C.}} = q_{all} \quad \text{---} (2) \quad B_{R.C.} , L_{R.C.}$$

يتم حل معادلتين فى مجهولين و تحديد قيمه كلا من $B_{R.C.}$, $L_{R.C.}$

بعد حساب $B_{R.C.}$ & $L_{R.C.}$ يقربا لاقرب ٥٠ مم بالزياده

$$B_{P.C.} = B_{R.C.} + 2\ t_{P.C.}$$

$$L_{P.C.} = L_{R.C.} + 2\ t_{P.C.}$$

Check .

$$F_2 = \frac{N}{B_{R.C.} * L_{R.C.}} - \frac{6M}{B_{R.C.} * L^2_{R.C.}} > Zero$$

F_2 F_1

حتى لا يكون هناك tension على التربه .

IF $F_2 < Zero$ ⟶ أى tension على التربه .

F_2 F_1

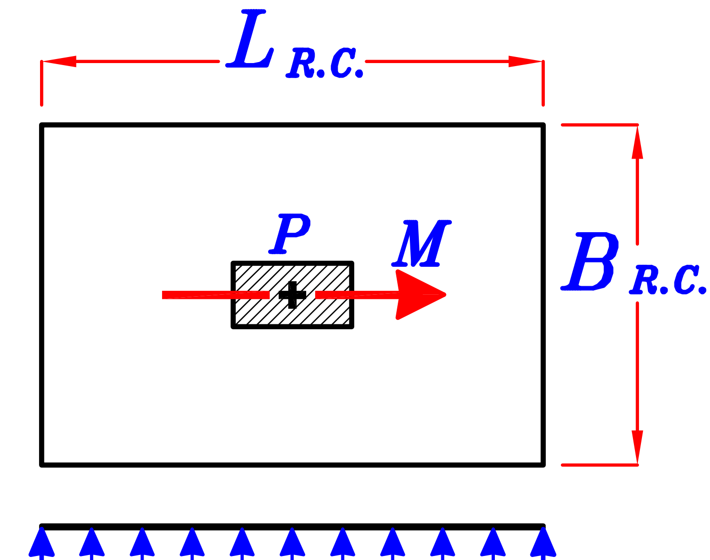
Increase $B_{R.C.}$, $L_{R.C.}$

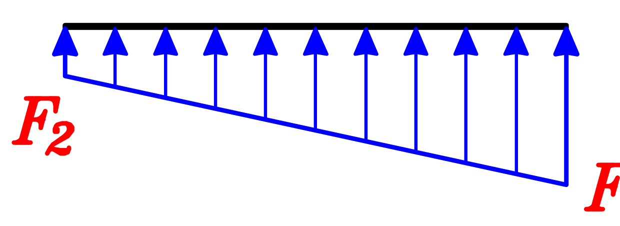
2- Design the critical sections For moment. (Depth of R.C. Footing.)

The actual ultimate limits stresses on R.C. concrete.

$$F_1 = \frac{P_{U.L.}}{B_{R.C.} * L_{R.C.}} + \frac{6\, M_{U.L.}}{B_{R.C.} * L_{R.C.}^2}$$

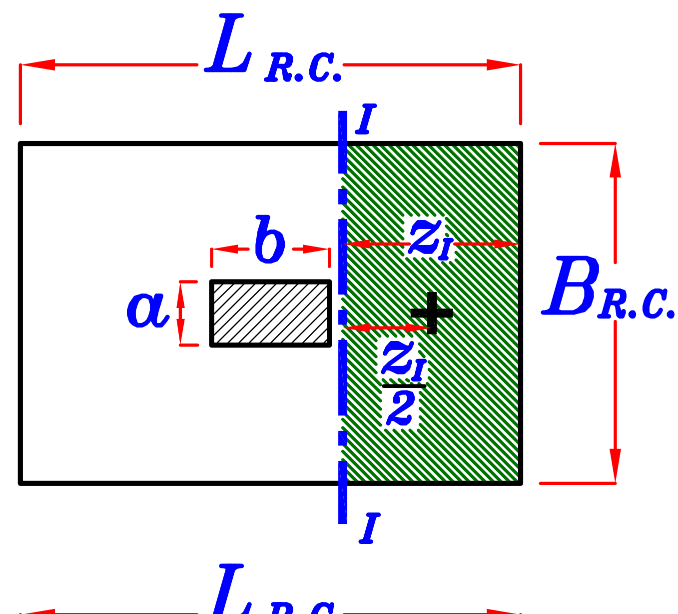
$$F_2 = \frac{P_{U.L.}}{B_{R.C.} * L_{R.C.}} - \frac{6\, M_{U.L.}}{B_{R.C.} * L_{R.C.}^2}$$





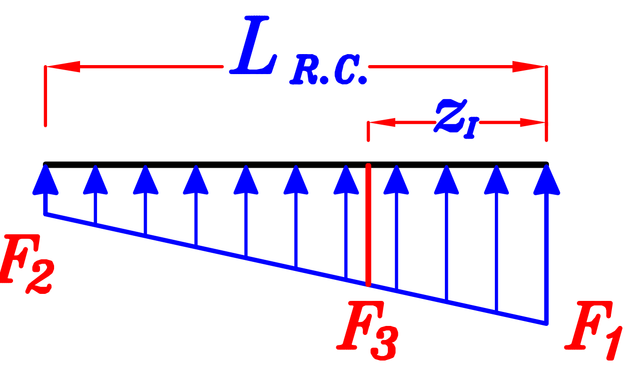
Direction I

$$z_I = \frac{L_{R.C.} - b}{2} \quad (m)$$



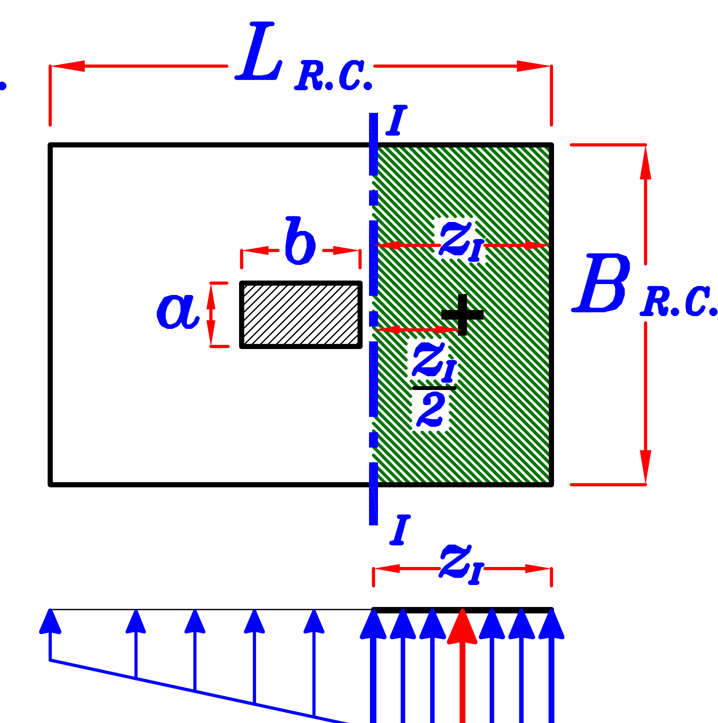
Calculate F_3 من تشابه المثلثات

$$F_3 = \frac{L_{R.C.} - z_I}{L_{R.C.}} * (F_1 - F_2) + F_2$$



Get the average stress $F_{1av.}$

$$F_{1av.} = \frac{F_1 + F_3}{2}$$

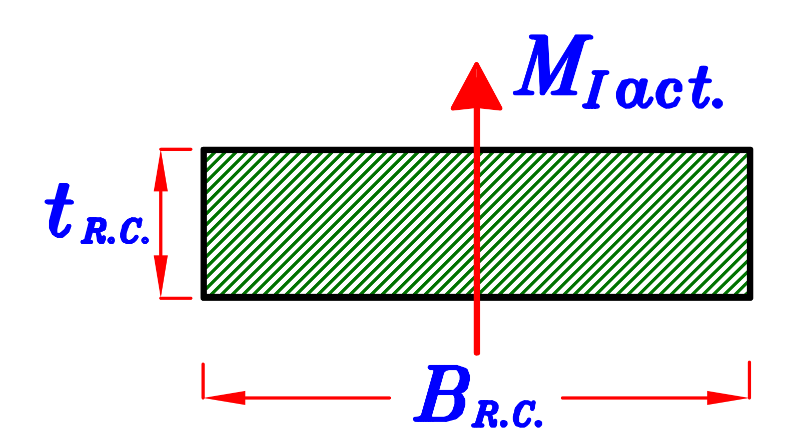


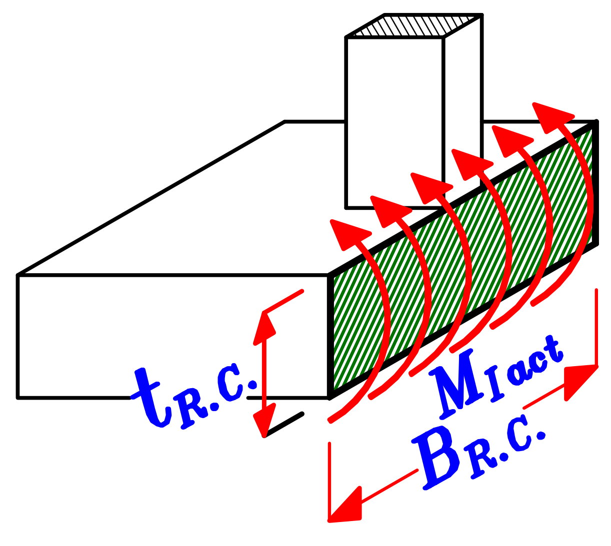
Force = Stress * Area

Force = $F_{1av.} * Z_I * B_{R.C.}$

Moment = Force * Distance

$$M_{I\,act.} = (F_{1av.} * Z_I * B_{R.C.}) \frac{Z_I}{2}$$ (kN.m. / B)





$$d_{I\,(mm)} = C_1 \sqrt{\frac{M_{I\,act.}\,(kN.m) * 10^6}{F_{cu}\,(N/mm^2) * B_{R.C.}\,(mm)}}$$

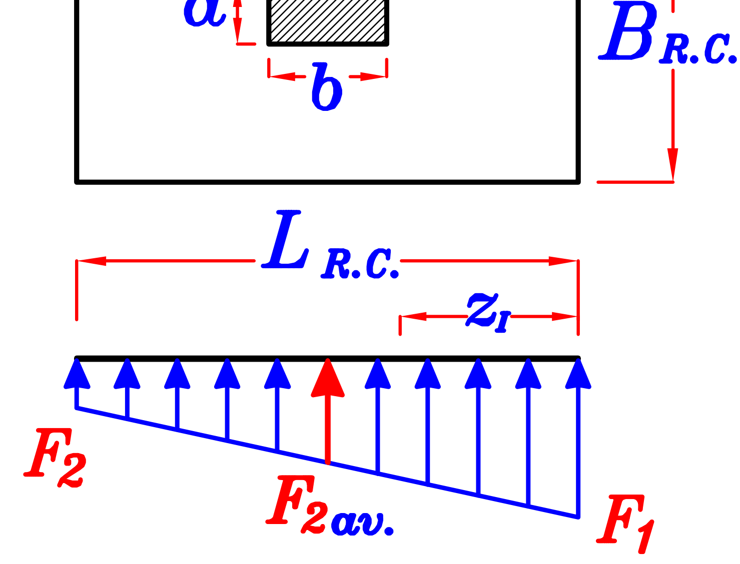
Choose $C_1 = (3.5 \rightarrow 5.0)$ Get d_I = ✓✓ (mm)

Take cover = 70 mm

$t_{I\,R.C.} = d_I + cover$ (70 mm) تقرب لاقرب ٥٠ مم بالزياده

Direction II

$$z_{II} = \frac{B_{R.C.} - a}{2} \quad (m)$$



Get the average stress $F_{2\,av.}$

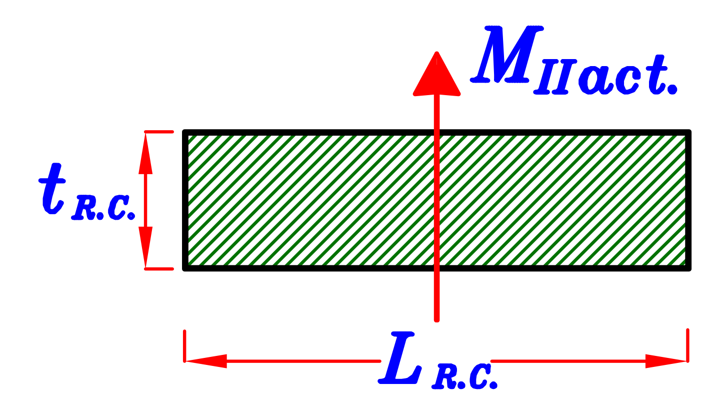
$$F_{2av.} = \frac{F_1 + F_2}{2}$$

Force = Stress * Area

Force = $F_{2av.} * z_{II} * L_{R.C.}$

Moment = Force * Distance

$$M_{II\,act.} = \left(F_{2av.} * z_{II} * L_{R.C.}\right) \frac{z_{II}}{2} \quad (kN.m./L)$$



$$d_{II}\,(mm) = C_1 \sqrt{\frac{M_{II\,act.} * 10^6}{F_{cu} * L_{R.C.}}}$$

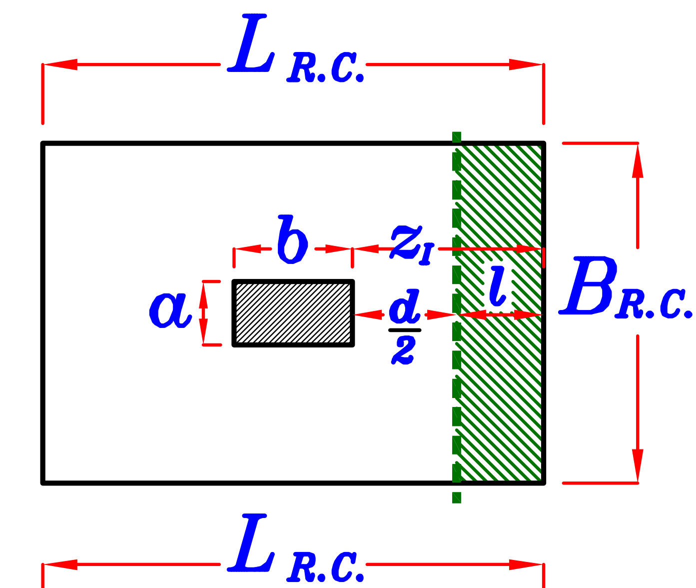
Choose $C_1 = (3.5 \rightarrow 5.0)$

Get $d_{II} = ✓✓$ (mm) Take cover = 70 mm

$t_{II\,R.C.} = d_{II} +$ cover (70 mm) تقرب لاقرب ٥٠ مم بالزياده

نأخذ الاكبر من $t_{II\,R.C.}$ & $t_{I\,R.C.}$ تكون هى $t_{R.C.}$

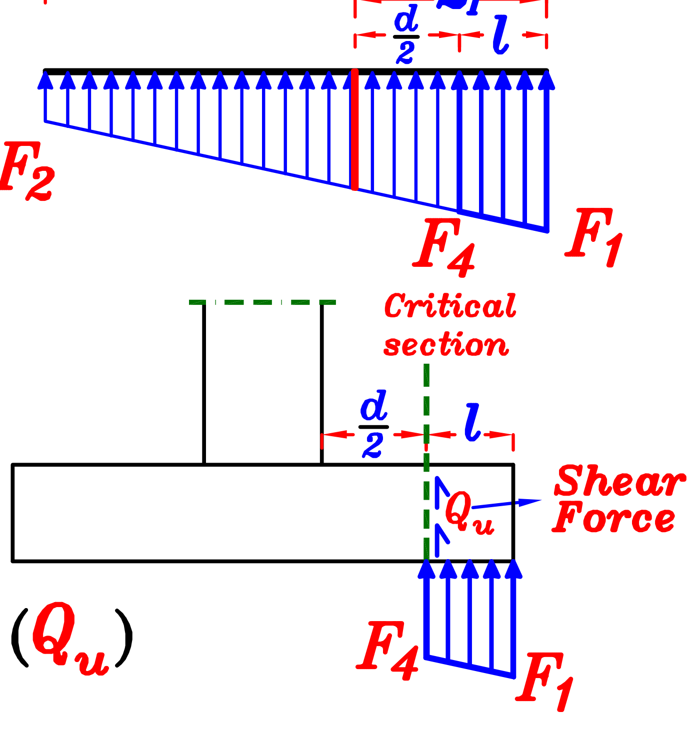
3 – Check Shear.



* Calculate $l = Z_I - \frac{d}{2}$ (m)



* Calculate the shear stress at critical section.



$$F_4 = \frac{L_{R.C.} - l}{L_{R.C.}} * (F_1 - F_2) + F_2$$

Get the average stress $F_{3av.}$

$$F_{3av.} = \frac{F_1 + F_4}{2}$$



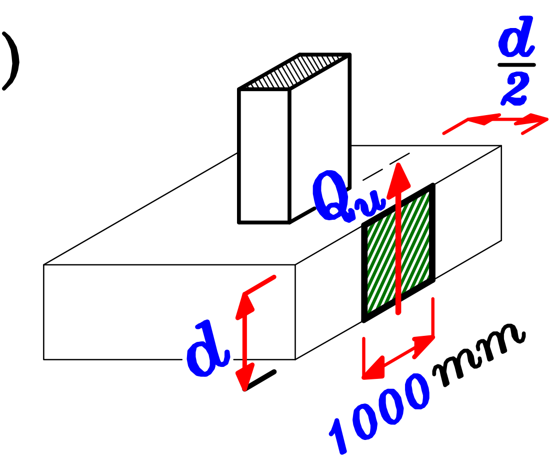
* Calculate Actual shear Force. (Q_u)

نحسب ل ١,٠ م طولى من القاعده

$$Q_u = F_{3av.} * l * 1.0\ m \quad (kN)$$

* Calculate Actual shear stress. (q_u)

$$q_u = \frac{Q_u}{b * d}$$



$$q_u = \frac{Q_{u\,(kN)} * 10^3}{1000_{(mm)} * d_{(mm)}} \quad (N/mm^2)$$

* Calculate Allowable shear stress. (q_{su})

$$q_{su} = 0.16\sqrt{\frac{F_{cu}}{\gamma_c}} \quad (N/mm^2)$$

* Compare between

Actual shear stress (q_u) & Allowable shear stress (q_{su})

* IF $q_u \leqslant q_{su}$ $\longrightarrow$ Safe shear stresses
No need to increase dimensions.

* IF $q_u > q_{su}$ $\longrightarrow$ UnSafe shear stresses
We have to increase dimensions.

IF UnSafe shear stresses increase $t_{R.C.}$ by 100 mm

then ReCheck:

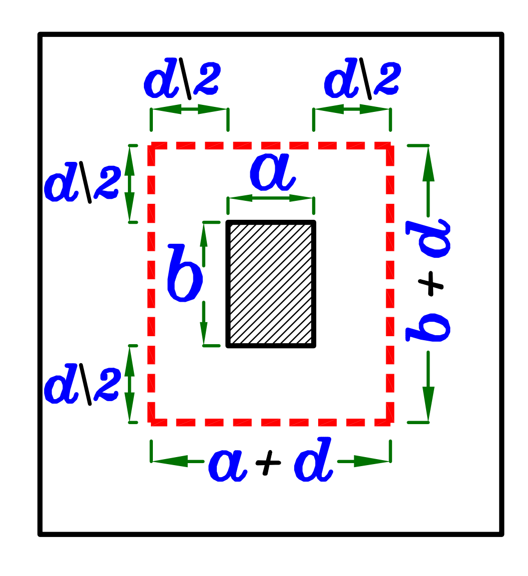
Actual shear stress (q_u) & Allowable shear stress (q_{su})

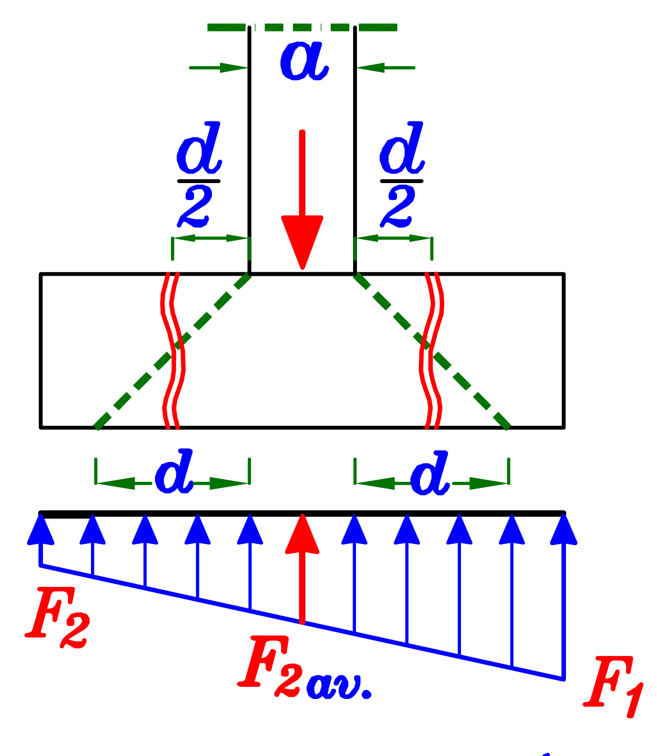
4 – Check Punching Shear. القص الثاقب .

The concrete area which resist punching shear.

تحديد مساحه الخرسانه المقاومه للقص الثاقب .

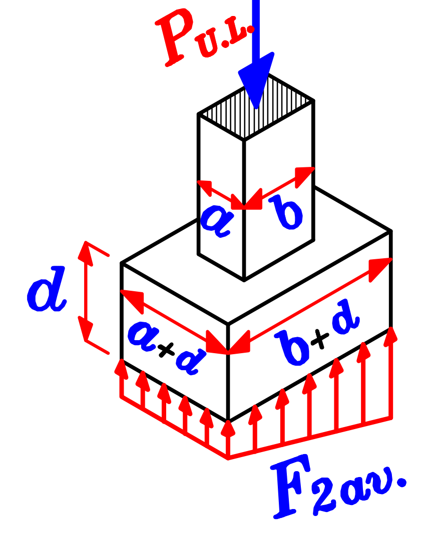
القطاع الحرج فى القص الثاقب عباره عن محيط يحيط بالعمود على مسافه $\frac{d}{2}$ من وش العمود من كل جهه .





Get the average stress $F_{2av.}$

$$F_{2av.} = \frac{F_1 + F_2}{2}$$



* **Calculate Punching Force.** (Q_p)

$$Q_p = P_{U.L.} - (F_{2av.})\left[(a+d)(b+d)\right]$$

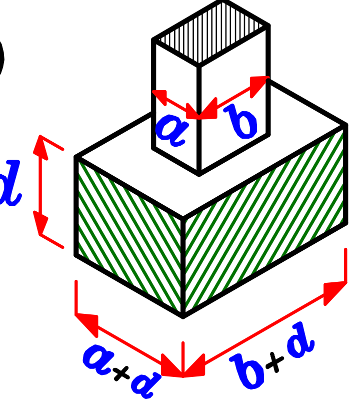
(kN)

* **Calculate Punching shear area.** (A_p)

المحيط العمق

$$A_p = \left[2(a+d) + 2(b+d)\right] * d$$

(mm^2)



* Calculate Actual Punching shear stress. q_{pu}

$$q_{pu} = \frac{\text{Punching Force}}{\text{Punching area}}$$

$$q_{pu} = \frac{Q_p\,(kN) * 10^3}{[2(a+d)+2(b+d)] * d} \quad (N/mm^2)$$

* Calculate allowable Punching shear stress. q_{pcu}

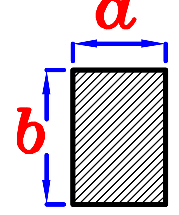
نأخذ القيمه الاقل من الاربع قيم التاليه .

$$q_{pcu} = 0.8\left(\frac{\alpha d}{b_o} + 0.2\right)\sqrt{\frac{F_{cu}}{\gamma_c}}$$

$\alpha = 4$ Interior Col.
$\alpha = 3$ Edge Col.
$\alpha = 2$ Corner Col.

b_o هو محيط الخرسانه التى سيحدث لها punching

$$q_{pcu} = 0.316\left(0.5 + \frac{a}{b}\right)\sqrt{\frac{F_{cu}}{\gamma_c}} \quad (N/mm^2)$$



a هو العرض الصغير للعمود

$$q_{pcu} = 0.316\sqrt{\frac{F_{cu}}{\gamma_c}} \quad (N/mm^2)$$

$$q_{pcu} = 1.60 \quad (N/mm^2)$$

---

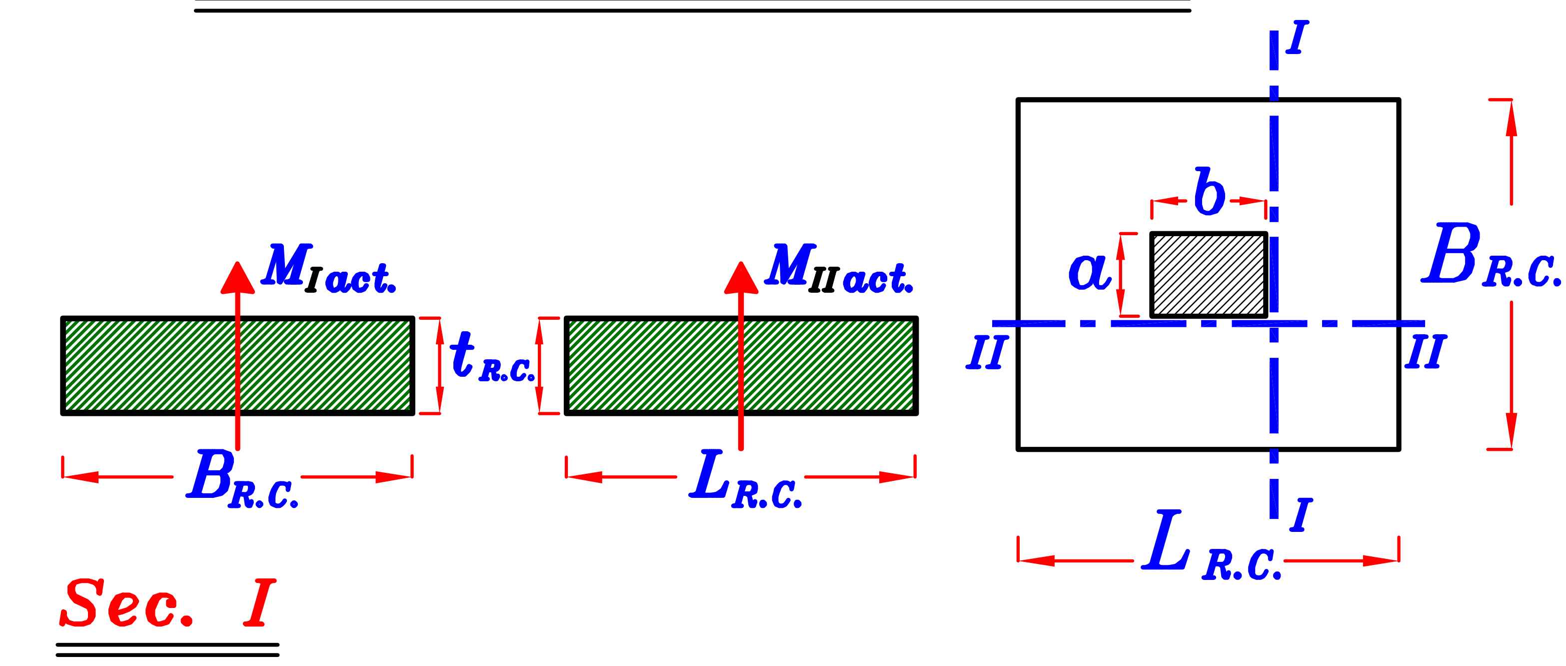
* Compare between

Actual punching shear stress (q_{pu}) & Allowable punching shear stress (q_{pcu})

* IF $q_{pu} \leq q_{pcu}$ ⟶ Safe punching shear. No need to increase dimensions.

* IF $q_{pu} > q_{pcu}$ ⟶ UnSafe punching shear. We have to increase dimensions.

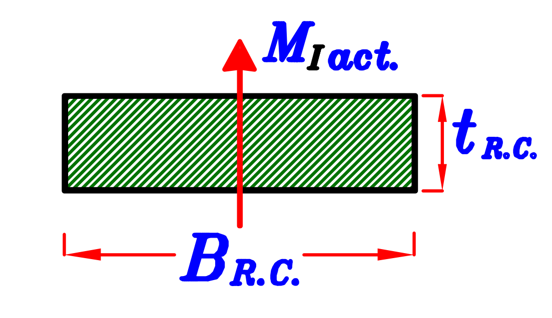
5- Reinforcement of the Footing.



Sec. I

From Step ② We Choose $C_1 = (3.5 \rightarrow 5.0)$

From $C_1 \xrightarrow{Get} J$



Get

$$A_{sI} = \frac{M_{I\,act.}}{J\,F_y\,d} \quad (mm^2)$$

Check $A_{s\,min}$

$$A_{s\,min}\ (mm^2/m) = \begin{cases} 1.5\,d\ (mm) \\ 5\,\phi\,12/m' \end{cases}$$ الأكبر

IF $A_{sI} \geqslant A_{s\,min} \longrightarrow$ o.k.

IF $A_{sI} < A_{s\,min} \longrightarrow$ Take $A_s = A_{s\,min}$

Sec. II

From Step ② We Choose $C_1 = (3.5 \rightarrow 5.0)$

From $C_1 \xrightarrow{Get} J$

Get $$A_{s\,II} = \frac{M_{II\,act.}}{J\,F_y\,d} \quad (mm^2)$$

$M_{II\,act.}$, $t_{R.C.}$, $L_{R.C.}$

Check $A_{s\,min}$

$$A_{s\,min}\ (mm^2/m) = \begin{cases} 1.5\,d\ (mm) \\ 5\phi 12/m' \end{cases}$$ الأكبر

IF $A_{s\,II} \geqslant A_{s\,min} \longrightarrow$ o.k.

IF $A_{s\,II} < A_{s\,min} \longrightarrow$ Take $A_s = A_{s\,min}$

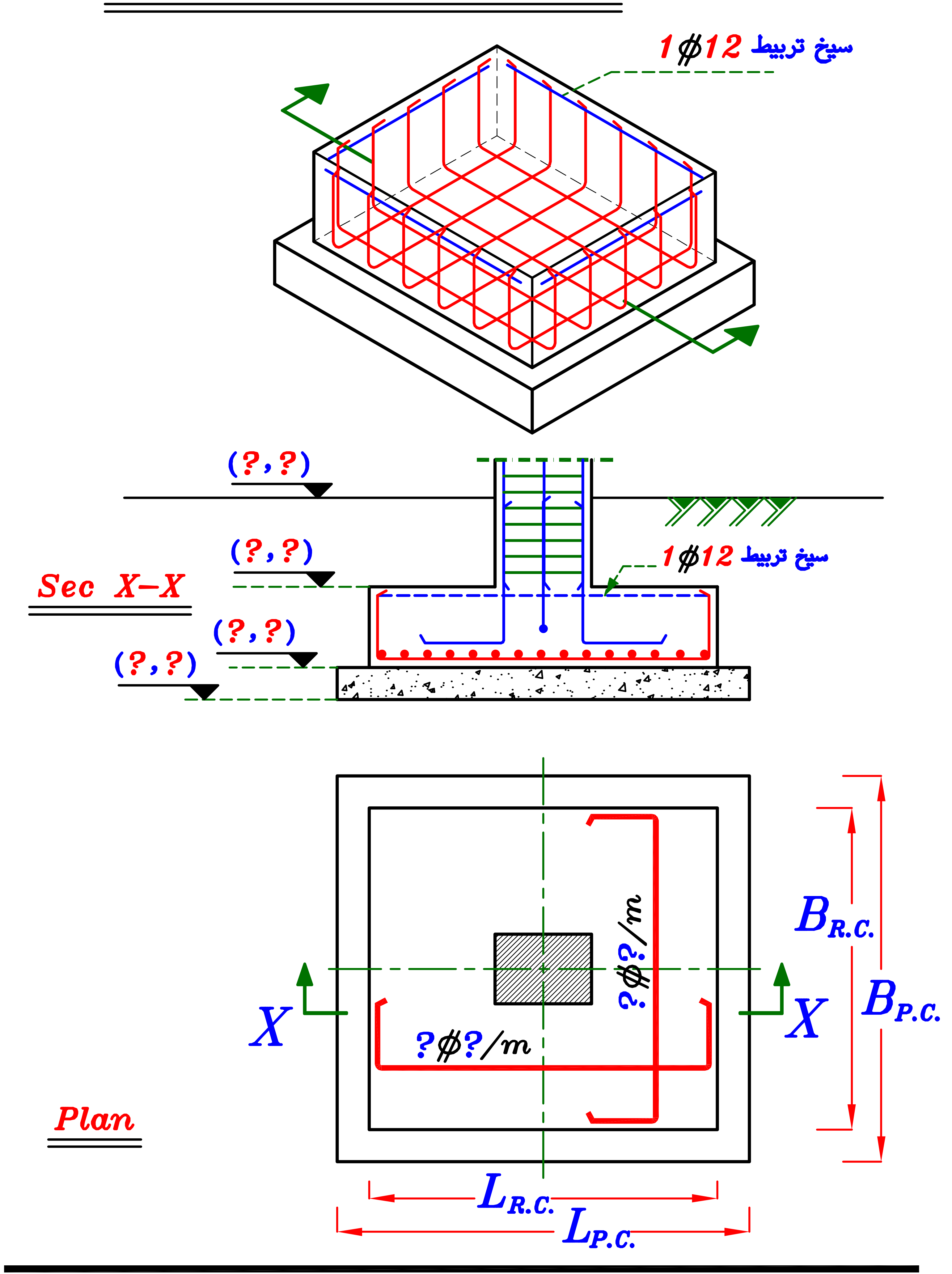
ملحوظه

فى حاله تحقيق الشرط $L - B = b - a$

سيكون $\frac{M_{II\,act.}}{L} = \frac{M_{I\,act.}}{B}$ و بالتالى من الممكن حساب A_s فى اتجاه

واحد فقط و يكون الاتجاه الاخر نفس القيمة $A_{s\,I} = A_{s\,II}$

6- Details of Reinforcement.



Example.

It is required to design a rectangular Footing to Support a R.C column of thickness (40 * 70) cm.
The column working load is 1500 kN and temporary moment → $M_y = 400$ kN.m

The allowable net bearing capacity in the Footing site is 150 kN/m². ($F_{cu} = 25$ N/mm², $F_y = 360$ N/mm²).
and draw details of RFT. to scale 1:50

Solution.

Data given. Column dimensions (400 * 700) mm

$P_{col.}$ (working) = 1500 kN $\quad$ $P_{col.}$ (U.L.) = 1500 * 1.5 = 2250 kN

$M_y = 400$ kN.m $\quad$ M_y (U.L.) = 400 * 1.5 = 600 kN.m

Bearing capacity of the soil = $q_{all} = 150$ kN/m²

$F_{cu} = 25$ N/mm² $\quad$ $F_y = 360$ N/mm²

1– Calculate the Footing area (Width & Length of R.C. Footing.)

Choose $t_{P.C.} = 30 \text{ cm} > 20 \text{ cm}$

$$L_{P.C.} - B_{P.C.} = b - a = 0.70 - 0.40 = 0.30 \text{ m}$$

$$L_{P.C.} = B_{P.C.} + 0.30 \text{ m} \quad \text{------} (1)$$

Actual Normal stress on soil = Bearing Capacity of soil.

$$F_1 = \frac{P}{B_{P.C.} * L_{P.C.}} + \frac{6\,M}{B_{P.C.} * L_{P.C.}^2} = q_{all} \quad \text{---(2)}$$

$$\frac{1500}{B_{P.C.} * L_{P.C.}} + \frac{6 * 400}{B_{P.C.} * L_{P.C.}^2} = 150 \quad \text{---(2)}$$

$$\therefore \quad \frac{1500}{B_{P.C.} * (B_{P.C.} + 0.30)} + \frac{6 * 400}{B_{P.C.} * (B_{P.C.} + 0.30)^2} = 150$$

$$B_{P.C.} = 3.607 \text{ m}$$

$B_{P.C.} = 3.70$ m	$L_{P.C.} = 4.0$ m
$B_{R.C.} = 3.10$ m	$L_{R.C.} = 3.40$ m

Check .

$$F_1 = \frac{P}{B_{P.C.} * L_{P.C.}} + \frac{6\,M}{B_{P.C.} * L_{P.C.}^2} < q_{all} = 150$$

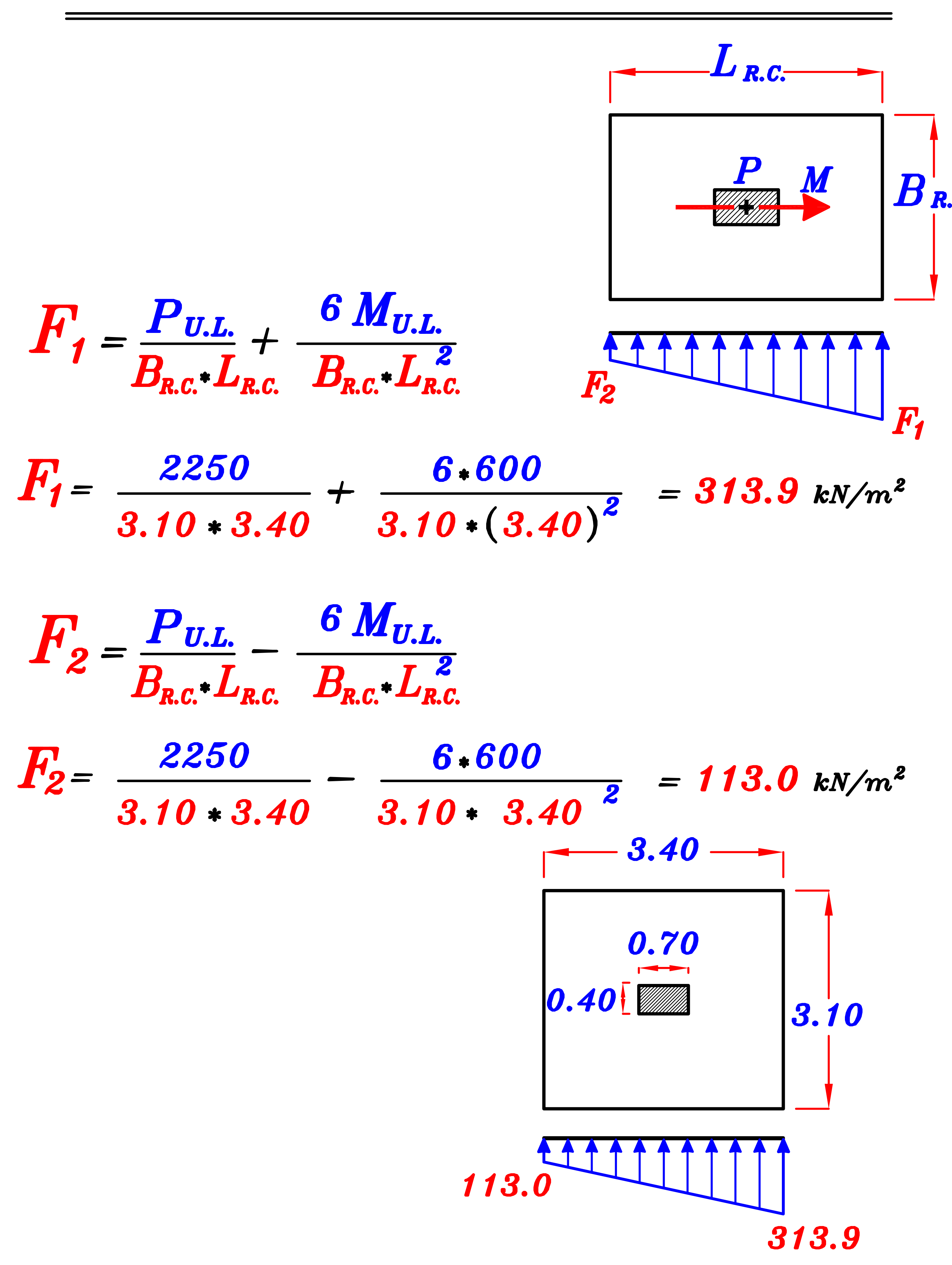
$$F_1 = \frac{1500}{3.70 * 4.0} + \frac{6 * 400}{3.70 * (4.0)^2} = 141.9 \text{ kN/m}^2 < q_{all} \quad \text{o.k.}$$

$$F_2 = \frac{P}{B_{P.C.} * L_{P.C.}} - \frac{6\,M}{B_{P.C.} * L_{P.C.}^2} > Zero$$

$$F_2 = \frac{1500}{3.70 * 4.0} - \frac{6 * 400}{3.70 * (4.0)^2} = 60.81 \text{ kN/m}^2 > Zero \quad \text{o.k.}$$

2- Design the critical sections For moment. (Depth of R.C. Footing.)

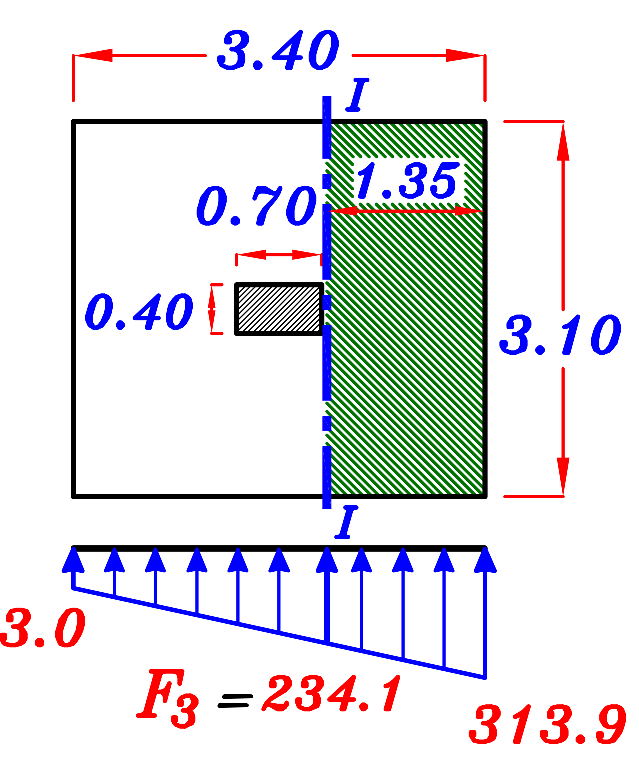
The actual ultimate Limits stresses on R.C. concrete.



Direction I

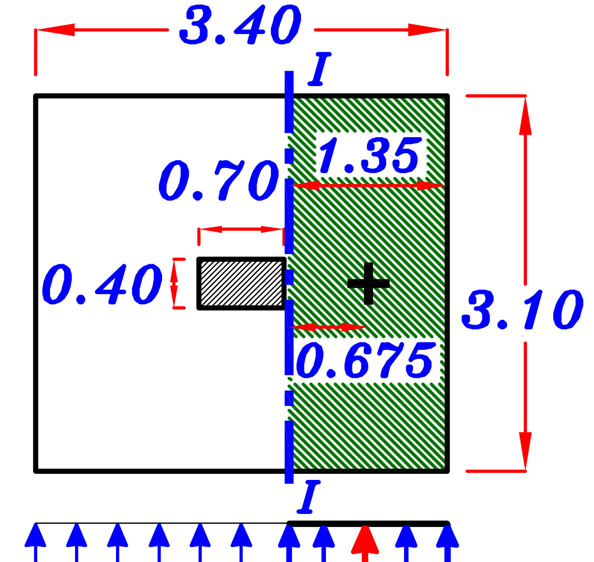
$$z_I = \frac{L_{R.C.} - b}{2} =$$

$$z_I = \frac{3.40 - 0.70}{2} = 1.35\ m$$



$$F_3 = \frac{L_{R.C.} - z_I}{L_{R.C.}} * (F_1 - F_2) + F_2$$

$$F_3 = \frac{3.40 - 1.35}{3.40} * (313.9 - 113.0) + 113.0 = 234.1\ kN/m^2$$



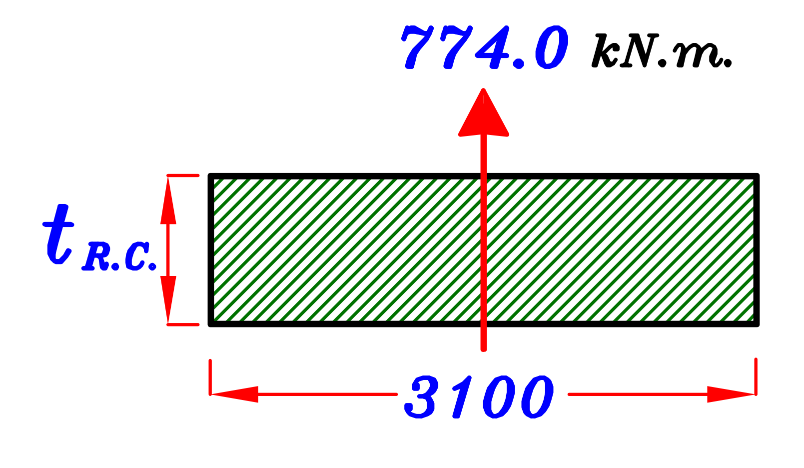
$$F_{1av.} = \frac{F_1 + F_3}{2}$$

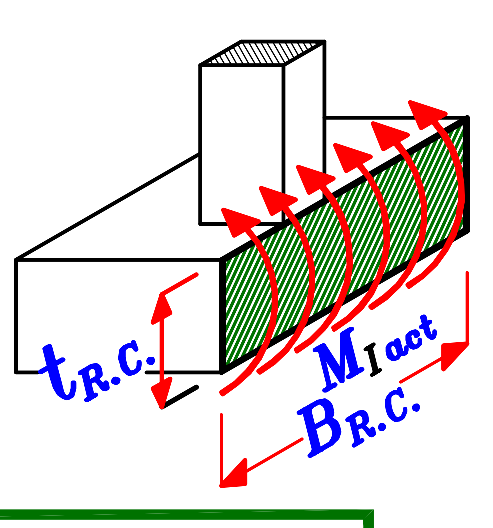
$$F_{1av.} = \frac{313.9 + 234.1}{2} = 274.0\ kN/m^2$$

moment = Force * Distance

$$M_{I\,act.} = (F_{1av.} * z_I * B_{R.C.})\ \frac{z_I}{2}$$

$$M_{I\,act.} = (274.0 * 1.35 * 3.10)\ \frac{1.35}{2} = 774.0\ kN.m$$



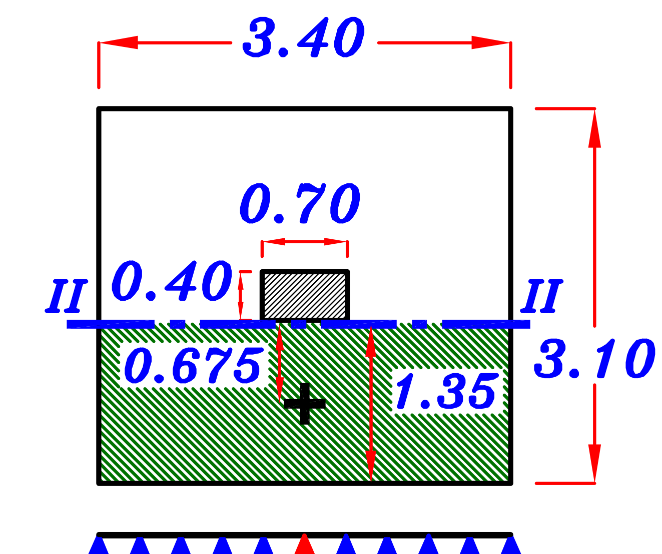


$$\because\ d_I = C_1 \sqrt{\frac{M_{I\,act.}}{F_{cu} * b}}$$

Choose $C_1 = 5.0$

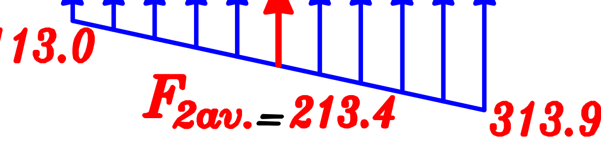
$$\therefore\ d_I = 5.0 \sqrt{\frac{774.0 * 10^6}{25 * 3100}} = 499.6\ mm$$

Direction II



$$Z_{II} = \frac{b_{R.C.} - a}{2} =$$

$$Z_{II} = \frac{3.10 - 0.40}{2} = 1.35\ m$$

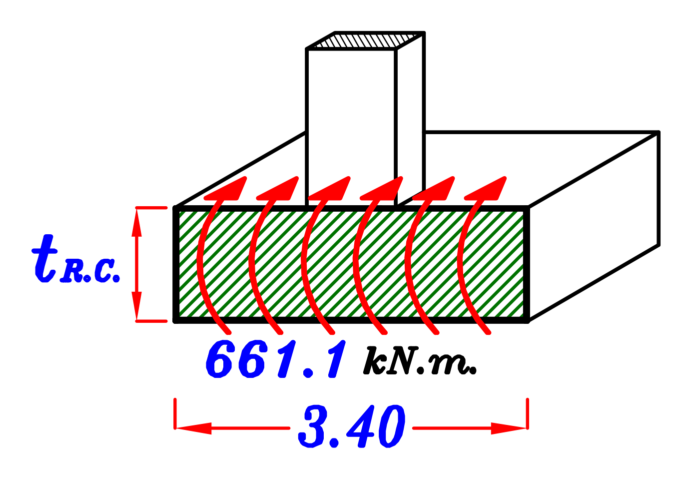


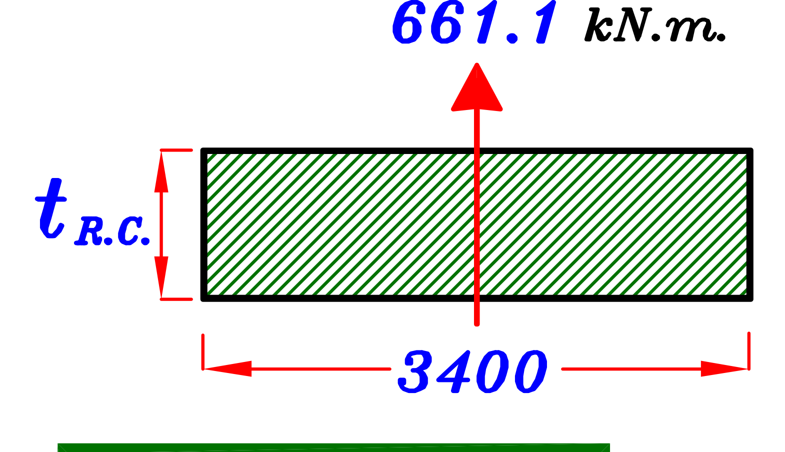
$$F_{2av.} = \frac{F_1 + F_2}{2}$$

$$F_{2av.} = \frac{313.9 + 113.0}{2} = 213.4\ kN/m^2$$

$$M_{II\,act.} = (F_{2av.} * Z_{II} * L_{R.C.})\ \frac{Z_{II}}{2}$$

$$M_{II\,act.} = (213.4 * 1.35 * 3.40)\ \frac{1.35}{2} = 661.1\ kN.m$$





$$\because\ d = C_1 \sqrt{\frac{M_{act.}}{F_{cu} * b}}$$

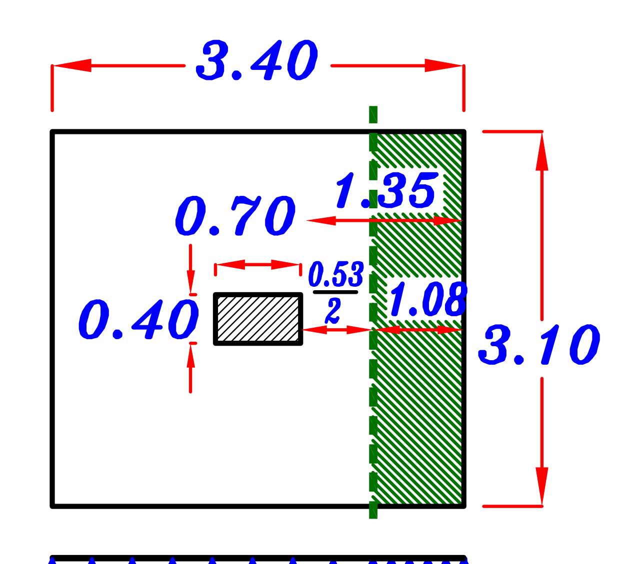
Choose $C_1 = 5.0$

$$\therefore\ d = 5.0 \sqrt{\frac{661.1 * 10^6}{25 \ * 3400}} = 440.9 \ mm$$

$$t_{R.C.} = d + 70 \ mm = 499.6 + 70 = 569.6 \ mm$$

$t_{R.C.} = 600 \ mm$ **$d = 530 \ mm$**

3- Check Shear.



* *Critical section For Shear.*

$$l = z_I - \frac{d}{2}$$

$$l = 1.35 - \frac{0.53}{2} = 1.08 \ m$$

* *Calculate the shear stress at critical section.*

$$F_4 = \frac{L_{R.C.} - l}{L_{R.C.}} * (F_1 - F_2) + F_2$$

$$F_4 = \frac{3.40 - 1.08}{3.40} * (313.9 - 113.0) + 113.0 = 250.1 \ kN/m^2$$

Get the average stress $F_{3av.}$

$$F_{3av.} = \frac{F_1 + F_4}{2}$$

Critical section

$\frac{d}{2}$ 1.08

Q_u Shear Force

F_4 F_1

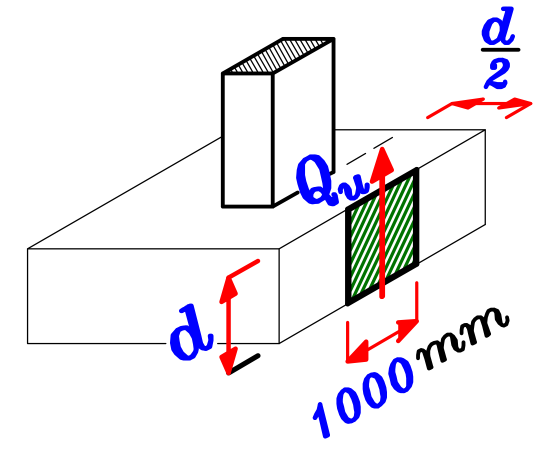
$$F_{3av.} = \frac{313.9 + 250.1}{2} = 282.0 \ kN/m^2$$

* Calculate Actual shear Force. (Q_u)

$$Q_u = F_{3av.} * l * 1.0 \ m = 282.0 * 1.08 * 1.0 \ m = 304.56 \ kN$$

* Calculate Actual shear stress. (q_u)

$$q_u = \frac{Q_u}{b * d} = \frac{304.56 * 10^3}{1000 * 530} = 0.574 \ N/mm^2$$



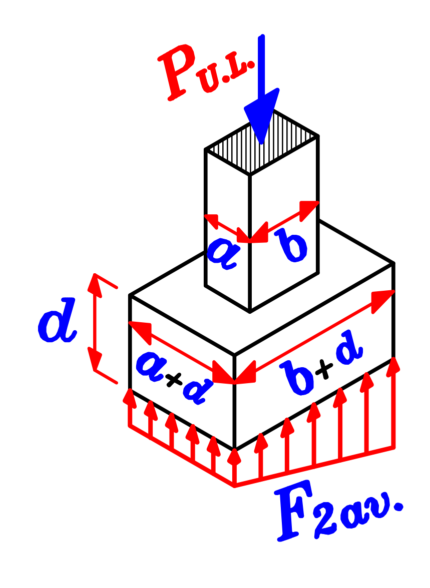
* Allowable shear stress. (q_{su})

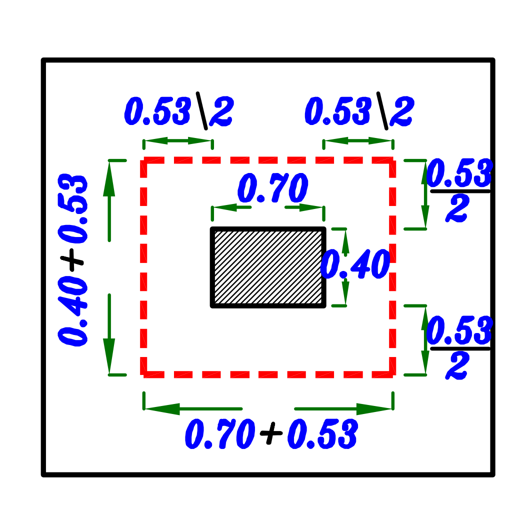
$$q_{su} = 0.16 \sqrt{\frac{F_{cu}}{\gamma_c}} = 0.16 \sqrt{\frac{25}{1.5}} = 0.653 \ N/mm^2$$

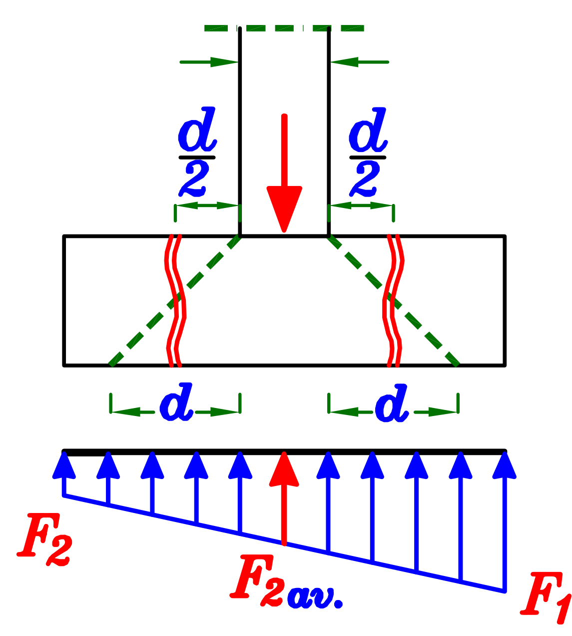
$$q_u < q_{su}$$ → Safe shear stresses

No need to increase dimensions.

4 – Check Punching Shear.







$$F_{2av.} = \frac{F_1 + F_2}{2} = \frac{313.9 + 113.0}{2} = 213.4 \ kN/m^2$$

$$a + d = 0.40 + 0.53 = 0.93 \ m$$

$$b + d = 0.70 + 0.53 = 1.23 \ m$$

* Calculate Punching Force. (Q_p)

$$Q_p = P_{U.L.} - (F_{2av})\left[(a+d)(b+d)\right]$$

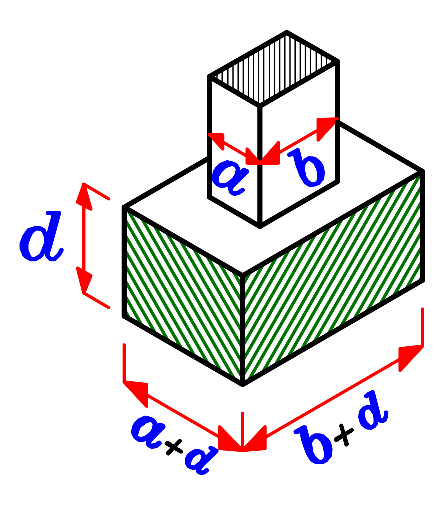
$$Q_p = 2250 - 213.4\left[0.93 * 1.23\right] = 2005.9 \ kN$$

* Calculate Punching shear area. (A_p)

$$A_p = \left[2(a+d) + 2(b+d)\right] * d$$

$$A_p = \left[2(400 + 530) + 2(700 + 530)\right] * 530$$

$$A_p = 2289600 \ mm^2$$



* Calculate Actual Punching shear stress. q_{pu}

$$q_{pu} = \frac{Q_p}{[2(a+d)+2(b+d)] * d}$$

$$q_{pu} = \frac{2005.9 * 10^3}{2289600} = 0.876 \ N/mm^2$$

* Calculate allowable Punching shear stress. q_{pcu}

نأخذ القيمه الاقل من الاربع قيم التاليه .

$$q_{pcu} = 0.8\left(\frac{\alpha\, d}{b_o} + 0.2\right)\sqrt{\frac{F_{cu}}{\gamma_c}}$$

$\alpha = 4$ Interior Col.

$$b_o = 2(a+d)+2(b+d) = 2(400+530)+2(700+530) = 4320 \ mm$$

$$q_{pcu} = 0.8\left(\frac{4*530}{4320} + 0.2\right)\sqrt{\frac{25}{1.5}} = 2.25 \ N/mm^2$$

$$q_{pcu} = 0.316\left(0.5 + \frac{a}{b}\right)\sqrt{\frac{F_{cu}}{\gamma_c}} \quad (N/mm^2)$$

a, b

$a = 0.40\, m$, $b = 0.70\, m$

$$q_{pcu} = 0.316\left(0.5 + \frac{0.40}{0.70}\right)\sqrt{\frac{25}{1.5}} = 1.38 \ N/mm^2$$

$$q_{pcu} = 0.316\sqrt{\frac{F_{cu}}{\gamma_c}} = 0.316\sqrt{\frac{25}{1.5}} = 1.29 \ N/mm^2$$

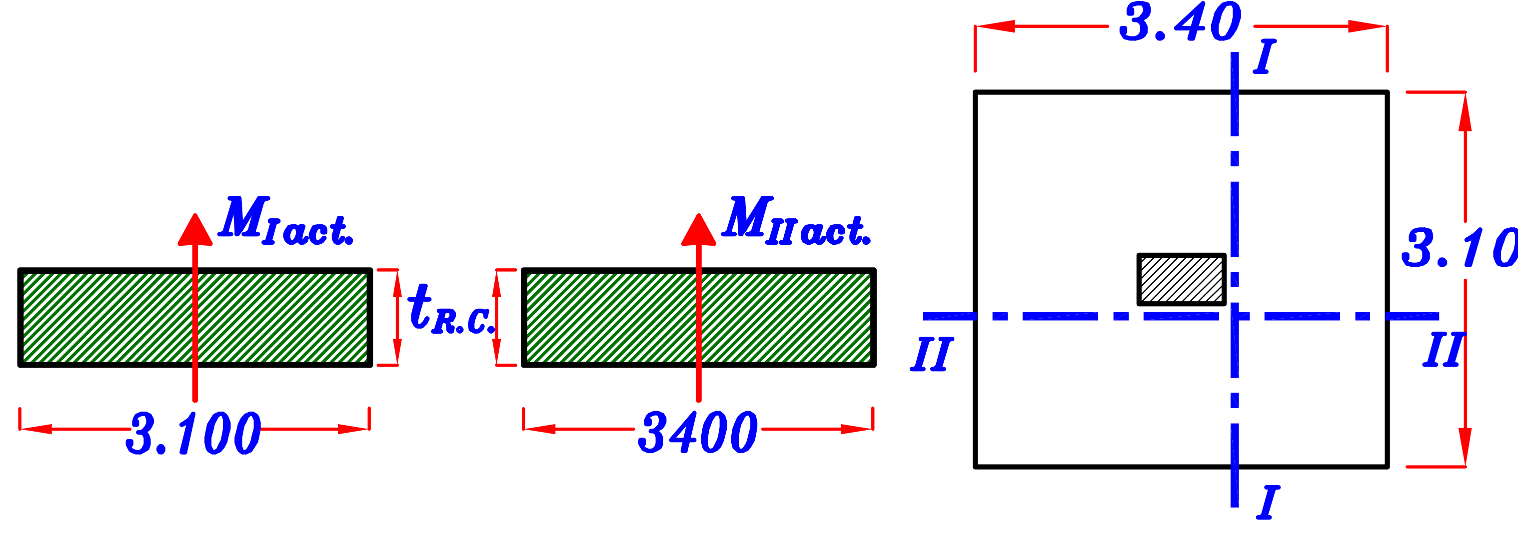
$$q_{pcu} = 1.60 \quad (N/mm^2)$$

$\therefore$ $q_{pcu} = 1.29 \ N/mm^2$ نأخذ القيمه الاقل من الاربع قيم السابقه .

$q_{pu} = 0.876 \ N/mm^2$

$q_{pu} \leq q_{pcu} \longrightarrow$ Safe punching shear. No need to increase dimensions.

5- Reinforcement of the Footing.



3.40
I
0.70
1.35
0.40
0.765
3.10

$$M_{I\,act.} = 774.0 \ kN.m$$

$$J = 0.826$$

$$A_s = \frac{M_{I\,act.}}{J \, F_y \, d} = \frac{774.0 * 10^6}{0.826 * 360 * 530} = 4911.1 \ mm^2$$

$$A_s \ (mm^2/m) = \frac{A_s}{B_{R.C.}} = \frac{4911.1}{3.10} = 1584.2 \ mm^2/m'$$

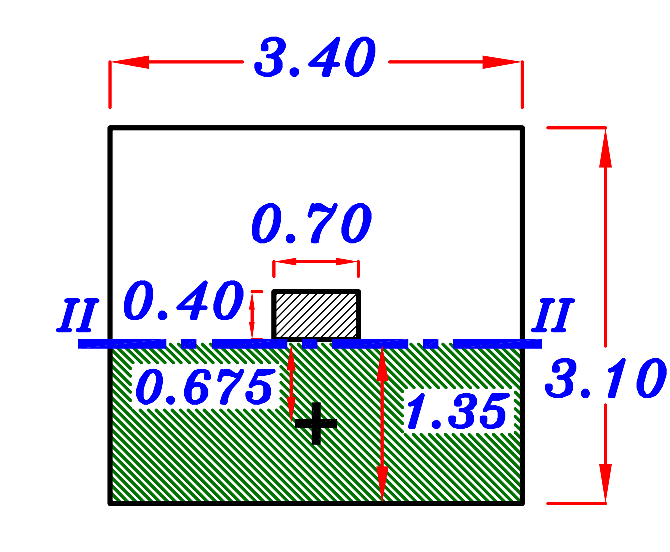
Check $A_{s\,min}$

$$A_{s\,min} = \left\{ \begin{array}{l} 1.5\,d = 1.5 * 530 = 795 \\ 5 \phi 12 / m' = 565.5 \end{array} \right\} 795 \ mm^2$$

$$\therefore A_s > A_{s\,min} \longrightarrow o.k.$$

$$A_s = 1584.2 \ mm^2 \qquad 7 \phi 18 / m'$$

$$M_{II\,act.} = 661.1 \text{ kN.m}$$



$$J = 0.826$$

$$A_s = \frac{M_{II\,act.}}{J\,F_y\,d} = \frac{661.1 * 10^6}{0.826 * 360 * 530} = 4194.7 \text{ mm}^2$$

$$A_s\,(mm^2/m) = \frac{A_s}{B_{R.C.}} = \frac{4194.7}{3.40} = 1233.7 \text{ mm}^2/m'$$

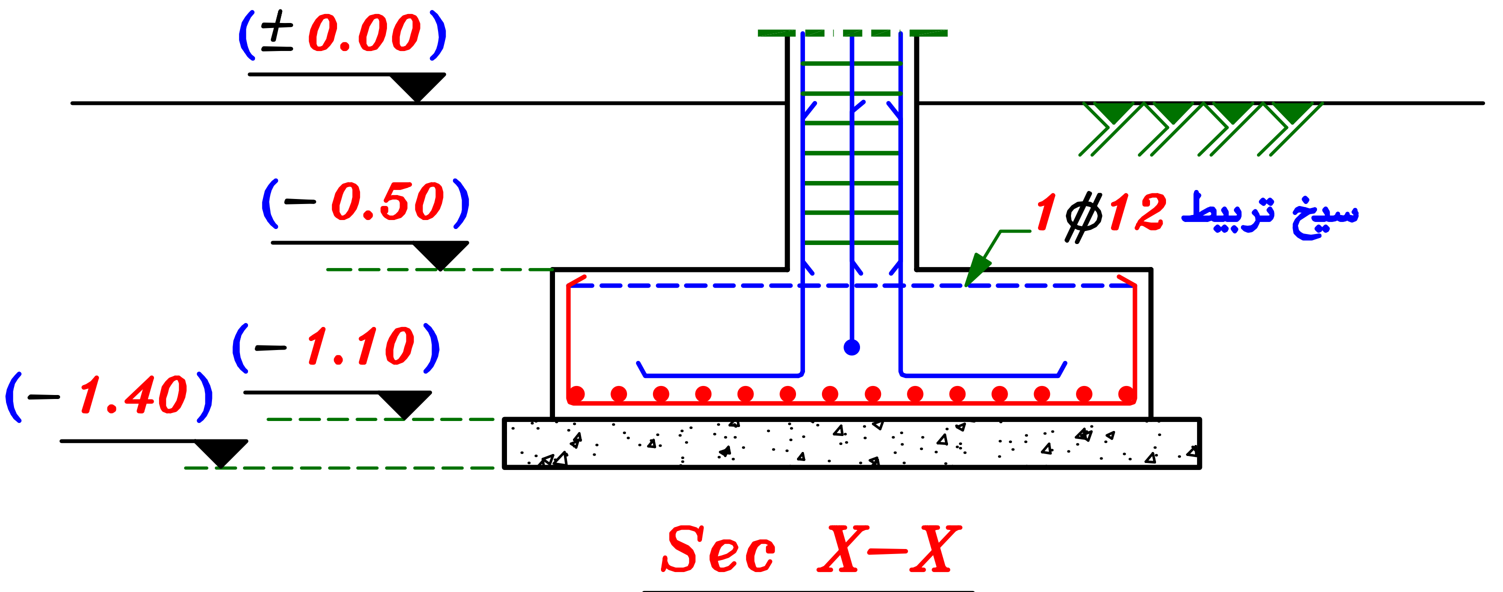
Check $A_{s\,min}$

$$A_{s\,min} = \left\{ \begin{array}{l} 1.5\,d = 1.5 * 530 = 795 \\ 5\,\phi\,12/m' = 565.5 \end{array} \right\} 795 \text{ mm}^2$$

$$\therefore\ A_s > A_{s\,min} \longrightarrow \text{o.k.}$$

$$A_s = 1233.7 \text{ mm}^2 \qquad \boxed{5\,\phi\,18/m'}$$

6– Details of Reinforcement.



Sec X–X

5ϕ18/m'

7ϕ18/m'

X

X

3.70

3.10

3.40

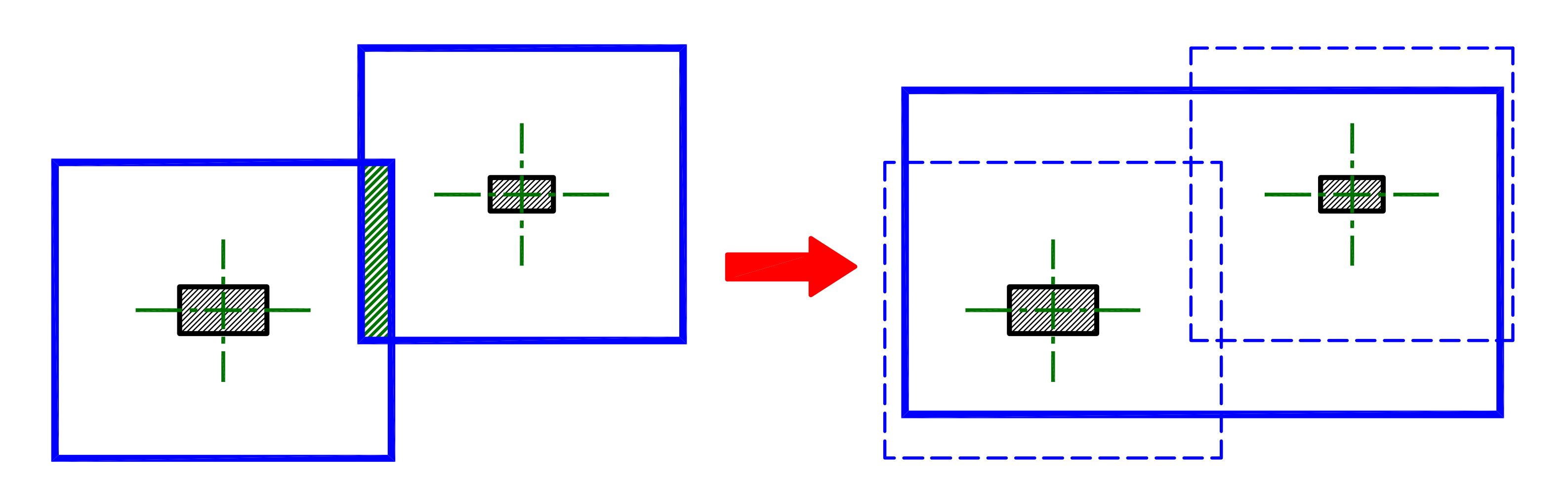
4.0

5 Design of Combined Footings.

تصميم القواعد المشتركه .

ـ القاعده المشتركه (*Combined Footing*) هى عباره عن قاعده واحده كبيره تحمل أكثر من عمود واحد و غالبا يكون شكلها مستطيل .

ـ عاده نحتاج لعمل قواعد مشتركه عند تداخل أكثر من قاعده منفصله .
أى عند تحديد أبعاد الـ *R.C.* لقاعدتين منفصلتين لعمودين متجاورين و وجد أن القاعدتين سوف يتداخلان معا و هو ما لا يمكن تنفيذه لذلك نلجأ لاستبدال القاعدتين المنفصلتين بقاعده واحده كبيره مشتركه بين العمودين .



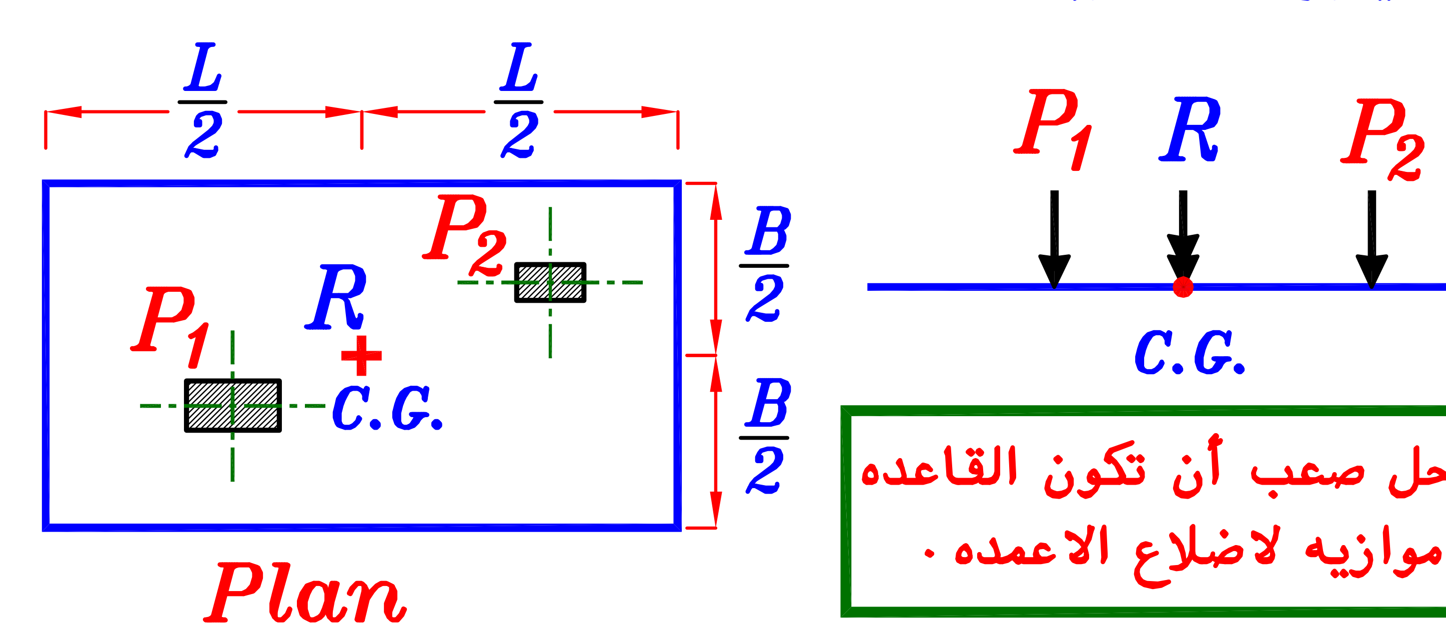
R.C. Isolated Footings *R.C. Combined Footing*

المبدأ الرئيسى لتصميم القواعد المشتركه .

نحاول قدر المستطاع أن يكون مركز الاحمال

يقع تماما عند C.G. القاعده المسلحه .

حتى يكون على التربه اجهادات منتظمه Uniform stresses

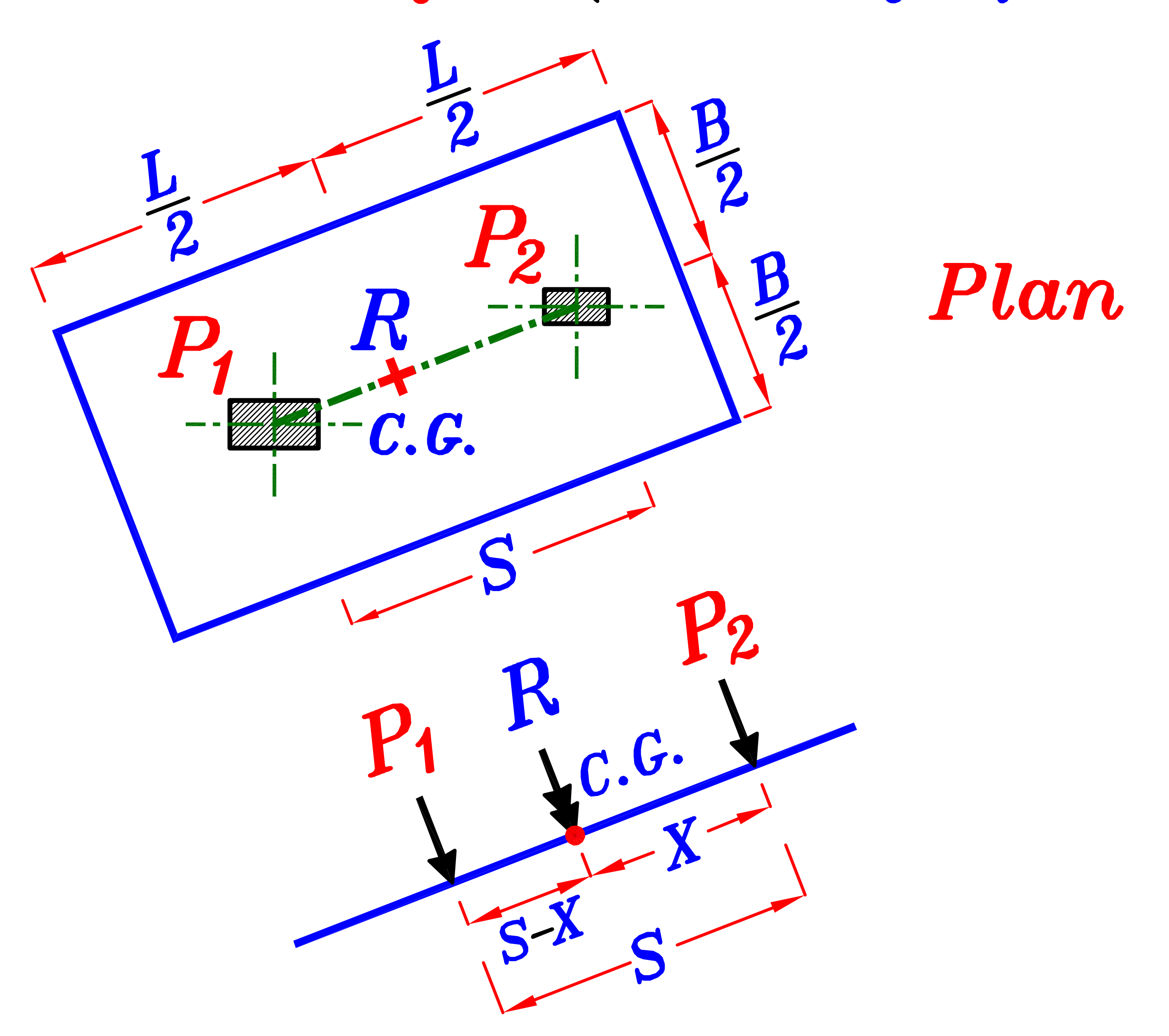


حل صعب أن تكون القاعده
موازيه لاضلاع الاعمده .

حل اسهل أن يكون اتجاه القاعده
موازى للخط الواصل بين العمودين .

Steps of design of rectangular combined Footing.

1– Calculate the Footing area. (Width & Length of R.C. Footing.)



$$R = P_1 + P_2$$

يتم حساب قيمه محصله الاحمال R

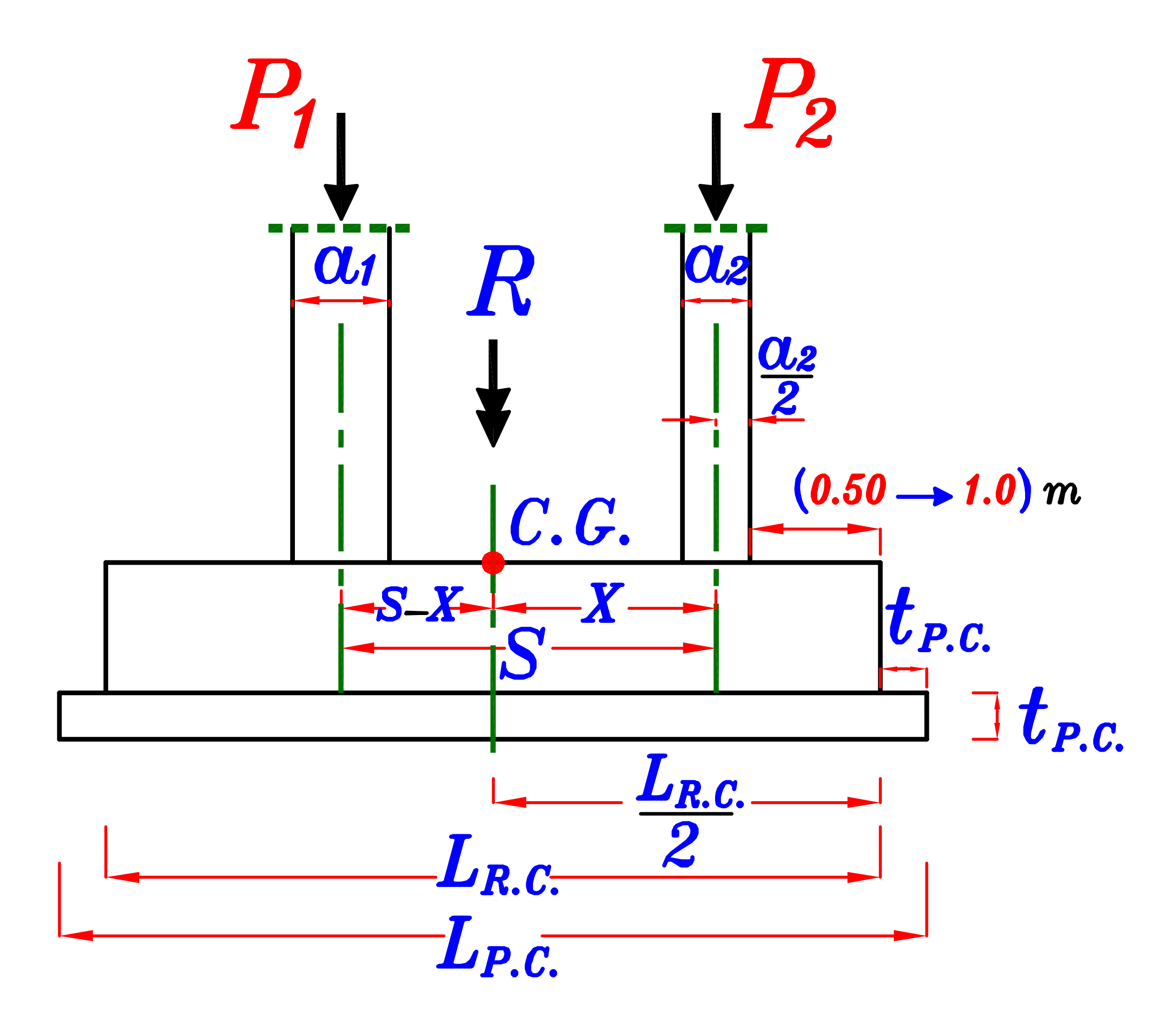
يتم تحديد مكان محصله الاحمال X

$$R * X = P_1 * S \longrightarrow X = \frac{P_1}{R} * S$$

نأخذ طول القاعده المسلحه بحيث تكون نهايتها بعد وش العمود الخارجى

بمسافه $(0.50\,m \rightarrow 1.0\,m)$ من جهه الحمل الاصغر .

مثلا فى هذا المثال P_2 هو الاصغر .



$$\frac{L_{R.C.}}{2} = (X) + \frac{a_2}{2} + (0.50 \rightarrow 1.0)\,m \longrightarrow \boxed{L_{R.C.} = \checkmark}$$

$$\therefore \boxed{L_{P.C.} = L_{R.C.} + 2\,t_{P.C.}}$$

Calculate the width of the Footing. B

IF $t_{P.C.} \geq 20$ cm get $B_{P.C.}$ From

$$A_{P.C.} = \frac{R_w}{q_{all}} = \checkmark \; m^2 = B_{P.C.} * L_{P.C.} \longrightarrow \boxed{B_{P.C.} = \checkmark}$$

$$\boxed{B_{R.C.} = B_{P.C.} - 2\, t_{P.C.}}$$

IF $t_{P.C.} < 20$ cm get $B_{R.C.}$ From

$$A_{R.C.} = \frac{R_w}{q_{all}} = \checkmark \; m^2 = B_{R.C.} * L_{R.C.} \longrightarrow \boxed{B_{R.C.} = \checkmark}$$

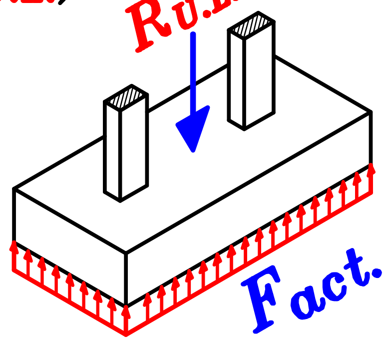
$$\boxed{B_{P.C.} = B_{R.C.} + 2\, t_{P.C.}}$$

2- Design the critical sections For moment. (Depth of R.C. Footing.)

$$P_{1\,U.L.} = 1.5 * P_{1w} \;,\; P_{2\,U.L.} = 1.5 * P_{2w} \;,\; R_{U.L.} = 1.5 * R_w$$

- Actual Normal stress on R.C. Footing (U.L.)

$$\boxed{F_{act.} = \frac{R_{U.L.}}{B_{R.C.} * L_{R.C.}}} \quad (kN/m^2)$$



- Actual Uniform Load on R.C. Footing (U.L.) as a beam.

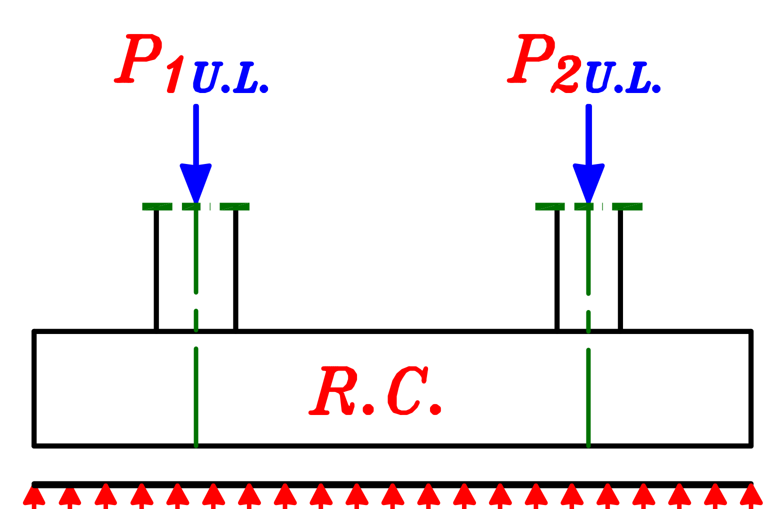
$B_{R.C.}$ نعتبر أن القاعده عباره عن كمره بعرض

$$\boxed{w_{U.L.} = \frac{R_{U.L.}}{L_{R.C.}}} \quad (kN/m')$$

Drawing U.L. B.M.D. & S.F.D. on all R.C. Footing.

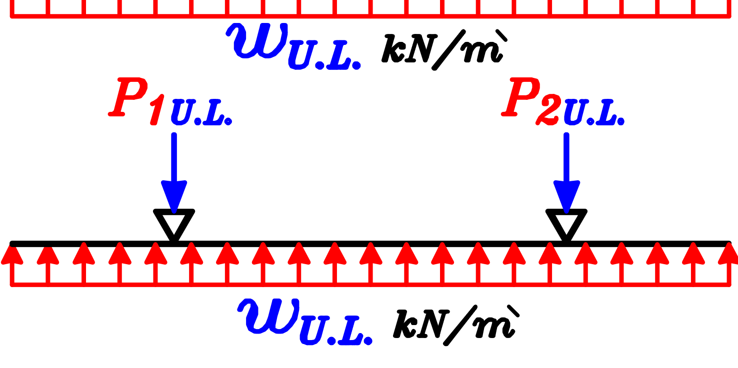
Longitudinal direction.

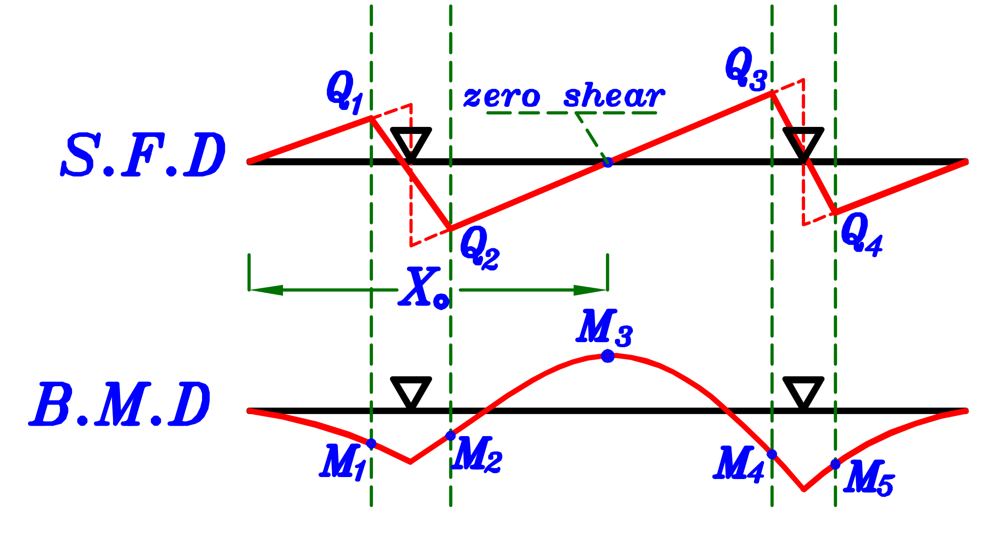
نعتبر أن القاعده عباره عن كمره بعرض $B_{R.C.}$



يتم رسم B.M.D. ، S.F.D. للقاعده كلها كأنها كمره بعرض $B_{R.C.}$

و يتم حساب قيم B.M. ، S.F. على وش الاعمده .





لتحديد أكبر moment فى منتصف القاعده M_3

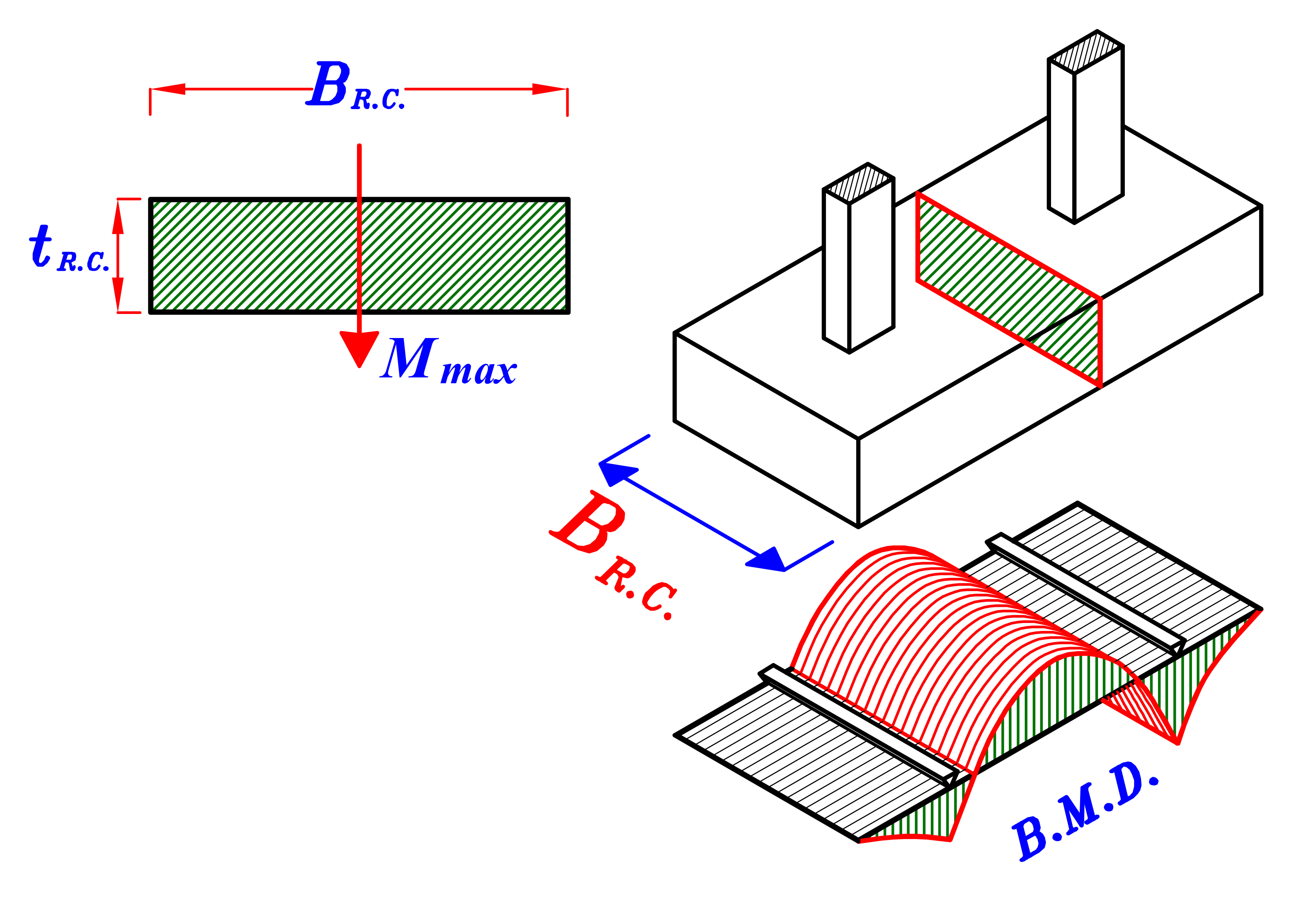
يتم تحديد مكان نقطه zero shear أى حساب المسافه X_o

$P_{1U.L.} = w_{U.L.} * X_o$ → $X_o = ✓$ → $M_3 = ✓$

Get M_{max}

نحسب أكبر moment على القاعده كلها . M_{max}

M_{max} is the biggest moment of M_1, M_2, M_3, M_4, M_5



$$d_{(mm)} = C_1 \sqrt{\frac{M_{max\,(kN.m)} * 10^6}{F_{cu\,(N/mm^2)} * B_{R.C.\,(mm)}}}$$

Choose $C_1 = (3.5 \rightarrow 5.0)$

يفضل فى القواعد أن نختار قيمه كبيره لـ C_1
حتى تكون تخانه القاعده كبيره
لضمان أن تكون القاعده Rigid

Get $d = \checkmark\checkmark$ (mm)

Take cover = 70 mm

يفضل أن يكون الـ cover فى القواعد كبير
لحمايه الحديد من الصدأ .

$t_{R.C.} = d + cover\ (70\ mm)$

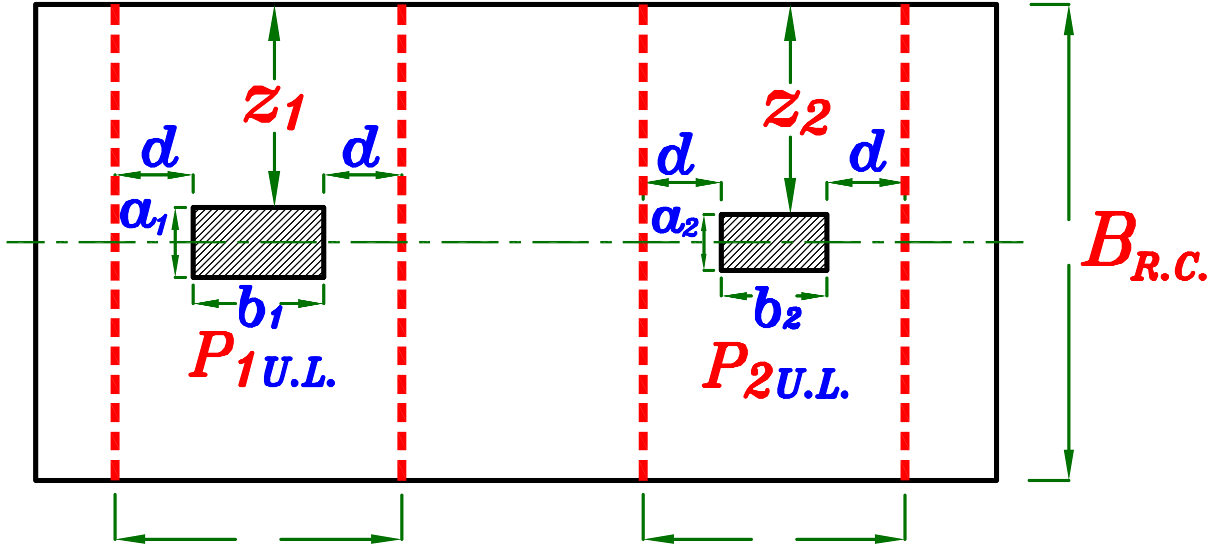
تقرب لاقرب ٥٠ مم بالزياده

As a Hidden Beam.



نعتبر القاعده أسفل كل عمود كأنها كمره مدفونه (Hidden Beam)

أبعادها أسفل العمود $L * B_{R.C.}$



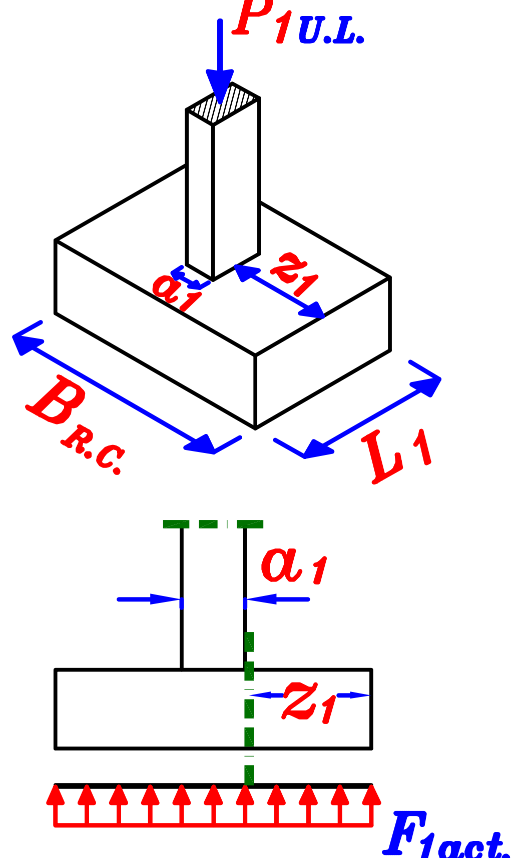
Hidden Beam 1

$$F_{1act.} = \frac{P_{1\,U.L.}}{B_{R.C.} * L_1} \quad (kN/m^2)$$

$$Z_1 = \frac{B_{R.C.} - a_1}{2} \quad (m)$$

$$M_{1act.} = (F_{1act.} * Z_1 * 1.0\,m)\ \frac{Z_1}{2}$$

$(kN.m/1.0\,m)$



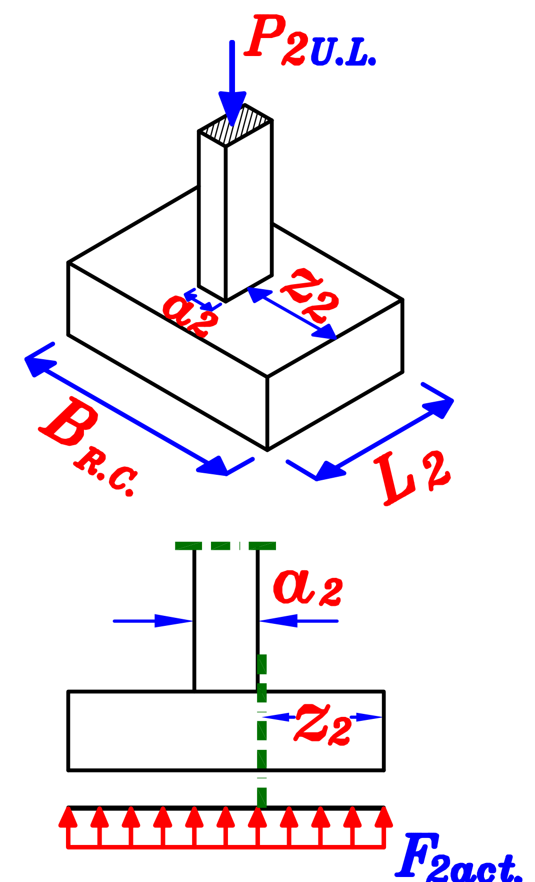
Hidden Beam 2

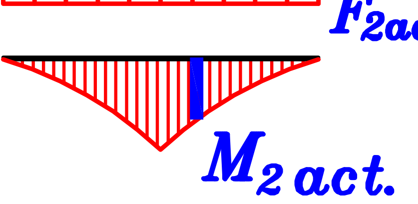
$$F_{2act.} = \frac{P_{2U.L.}}{B_{R.C.} * L_2} \quad (kN/m^2)$$

$$Z_2 = \frac{B_{R.C.} - a_2}{2} \quad (m)$$

$$M_{2act.} = (F_{2act.} * Z_2 * 1.0\,m)\ \frac{Z_2}{2}$$

$(kN.m/1.0\,m)$





Choose M_{bigger} The bigger value of $M_{1act.}$ & $M_{2act.}$

$$d = C_1 \sqrt{\frac{M_{bigger} * 10^6}{F_{cu} * 1000}} \xrightarrow{Get} C_1$$

Then Check on $C_1 \not< 3.0$

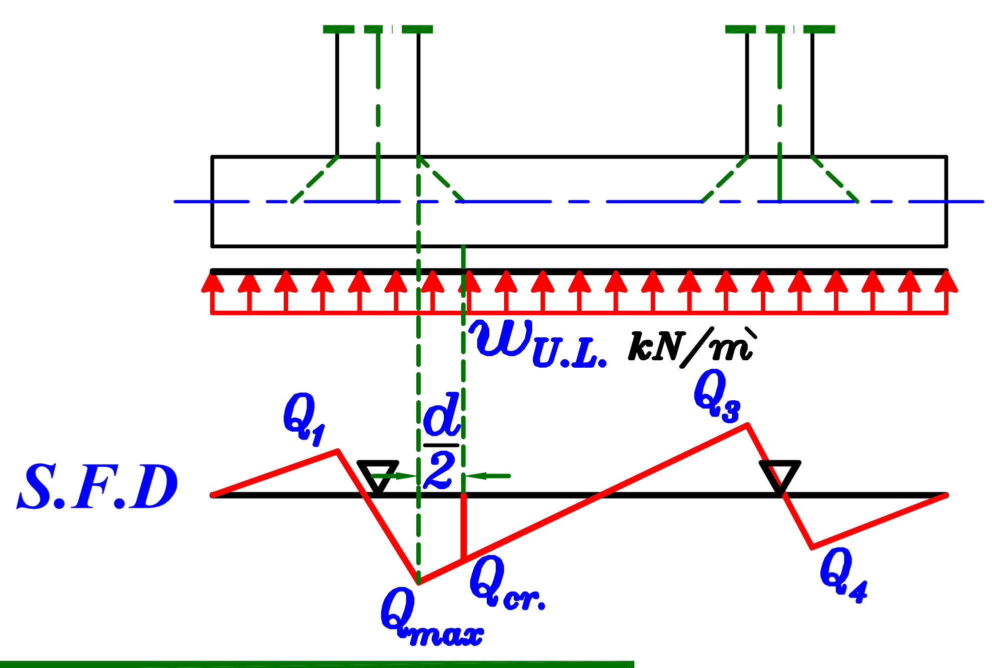
IF $C_1 < 3.0 \longrightarrow$ Increase d

and Recheck the transverse direction.

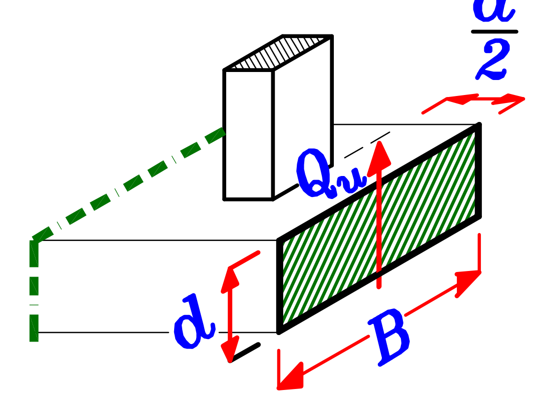
3- Check Shear. at long direction

Critical section For Shear.

على بعد d من وش العمود اللى عنده $Q_{max.}$



$$Q_{cr.} = Q_{max.} - w_{U.L.} * \frac{d}{2}$$



* Calculate Actual shear stress. (q_u)

$$q_u = \frac{Q_{cr.}(kN) * 10^3}{B(mm) * d(mm)} \quad (N/mm^2)$$

* Calculate Allowable shear stress. (q_{su})

$$q_{su} = 0.16\sqrt{\frac{F_{cu}}{\gamma_c}} \quad (N/mm^2)$$

* Compare between

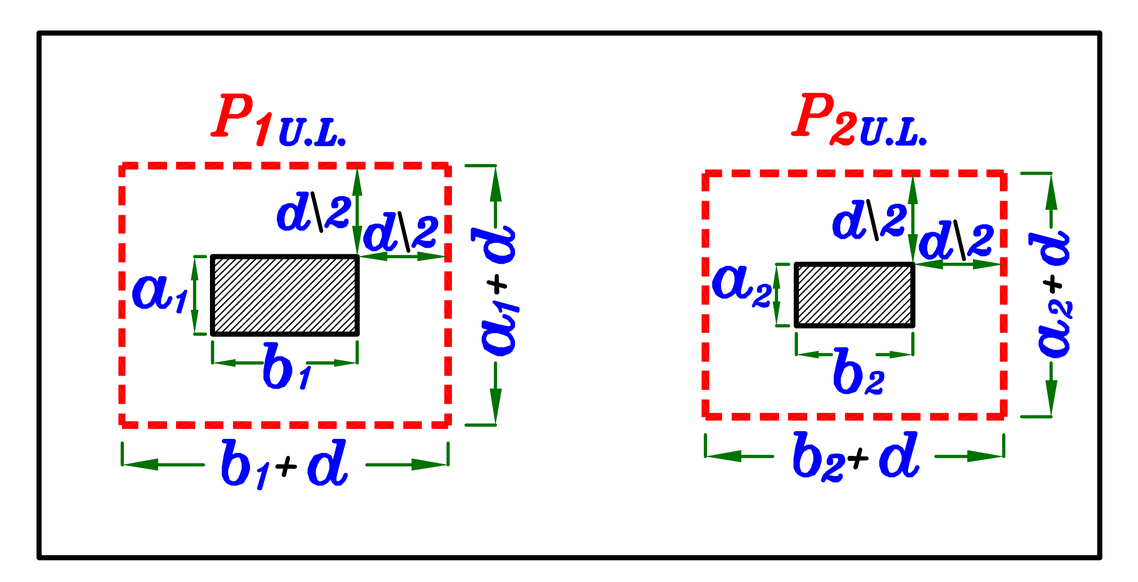
Actual shear stress (q_u) & Allowable shear stress (q_{su})

* IF $q_u \leqslant q_{su}$ ⟶ Safe shear stresses
No need to increase dimensions.

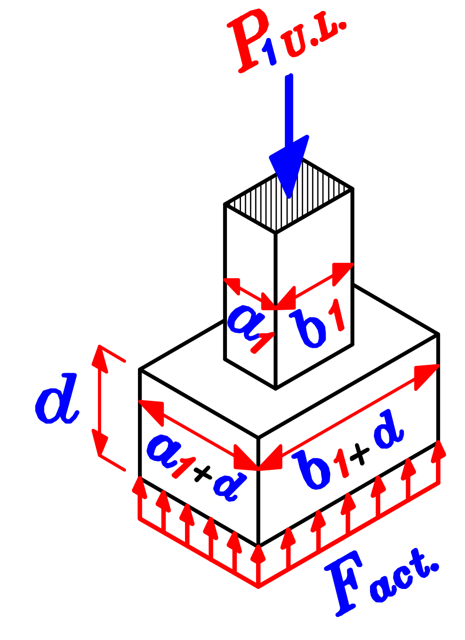
* IF $q_u > q_{su}$ ⟶ UnSafe shear stresses
We have to increase dimensions.

4 – Check Punching Shear.





Column 1



* Calculate Punching Force. (Q_{1p})

$$Q_{1p} = P_{1\,U.L.} - (F_{act.})\left[(a_1+d)(b_1+d)\right]$$

(kN)

* Calculate Punching shear area. (A_{1p})

المحيط   العمق

$$A_{1p} = \left[2(a_1+d)+2(b_1+d)\right] * d$$

(mm^2)

* Calculate Actual Punching shear stress. q_{1pu}

$$q_{1pu} = \frac{Q_{1p}\ (kN) * 10^3}{\left[2(a_1+d)+2(b_1+d)\right] * d\ (mm^2)}$$

(N/mm^2)

Column 2

* Calculate Punching Force. (Q_{2p})

$$Q_{2p} = P_{2\,U.L.} - (F_{act.})\left[(a_2 + d)(b_2 + d)\right]$$

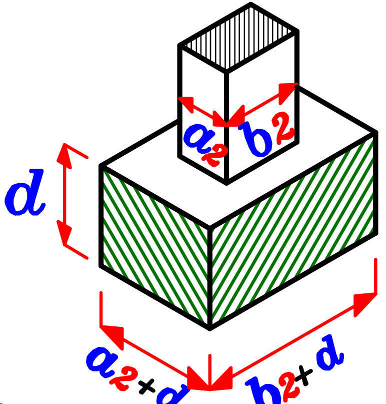
(kN)

* Calculate Punching shear area. (A_{2p})

المحيط العمق

$$A_{2p} = \left[2(a_2 + d) + 2(b_2 + d)\right] * d$$

(mm^2)



* Calculate Actual Punching shear stress. q_{2pu}

$$q_{2pu} = \frac{Q_{2p}\,(kN) * 10^3}{\left[2(a_2 + d) + 2(b_2 + d)\right] * d \;(mm^2)}$$

(N/mm^2)

Choose $q_{pu_{max}}$ the bigger value of q_{1pu} & q_{2pu}

* Calculate allowable Punching shear stress. q_{pcu}

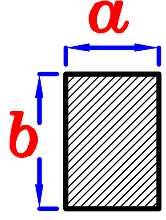
نأخذ القيمه الاقل من الاربع قيم التاليه .

$$q_{pcu} = 0.8\left(\frac{\alpha\, d}{b_o} + 0.2\right)\sqrt{\frac{F_{cu}}{\gamma_c}}$$

$\alpha = 4$ Interior Col.
$\alpha = 3$ Edge Col.
$\alpha = 2$ Corner Col.

b_o هو محيط الخرسانه التى سيحدث لها punching

$$q_{pcu} = 0.316\left(0.5 + \frac{a}{b}\right)\sqrt{\frac{F_{cu}}{\gamma_c}} \quad (N/mm^2)$$



a هو العرض الصغير للعمود

$$q_{pcu} = 0.316\sqrt{\frac{F_{cu}}{\gamma_c}} \quad (N/mm^2)$$

$$q_{pcu} = 1.60 \quad (N/mm^2)$$

* Compare between

The max. Actual punching shear stress ($q_{pu\,max}$)

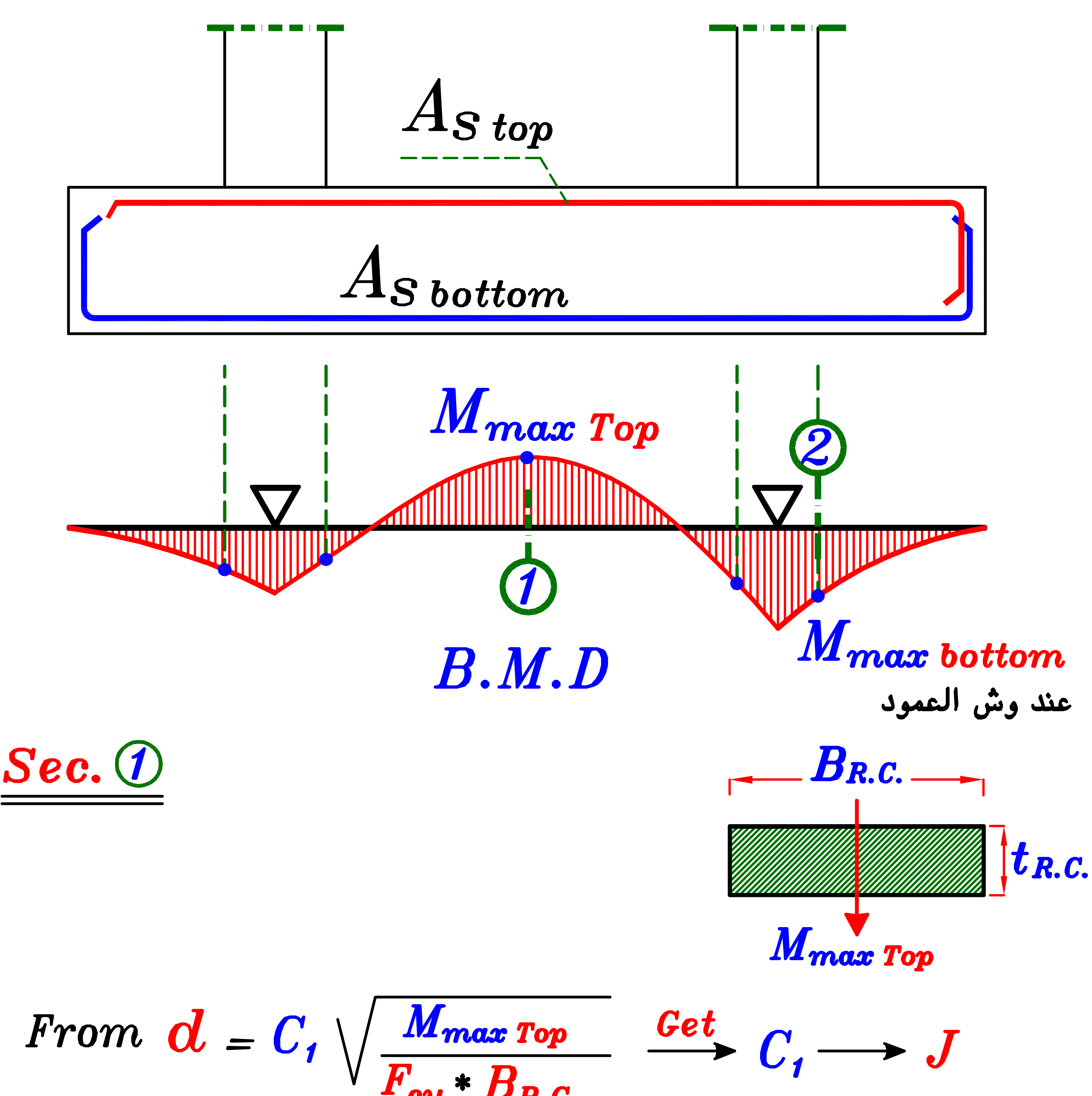
& Allowable punching shear stress (q_{pcu})

* IF $q_{pu\,max} \leq q_{pcu}$ ⟶ Safe punching shear. No need to increase dimensions.

* IF $q_{pu\,max} > q_{pcu}$ ⟶ UnSafe punching shear. We have to increase dimensions.

5- Reinforcement of the Footing.

Longitudinal direction.



Get

$$A_{S\,top} = \frac{M_{max\,Top}}{J\,F_y\,d} \quad (mm^2)$$

Check $A_{s_{min}}$

$$A_{s_{min}} \ (mm^2/m) = \begin{cases} 1.5\,d \ (mm) \\ 5\phi 12/m' \end{cases}$$ الأكبر

IF $A_{s_{top}} \geq A_{s_{min}} \longrightarrow$ o.k.

IF $A_{s_{top}} < A_{s_{min}} \longrightarrow$ Take $A_s = A_{s_{min}}$

$A_{s_{top}}$

عاده يتم رص الحديد العلوى فى القواعد
بحيث يتم عمل ركبه من جهه واحده فقط
للتوفير بحيث تكون الركبه مره من جهه
اليمين و السيخ التالى تكون
الركبه جهه اليسار

$5\phi 12/m'$

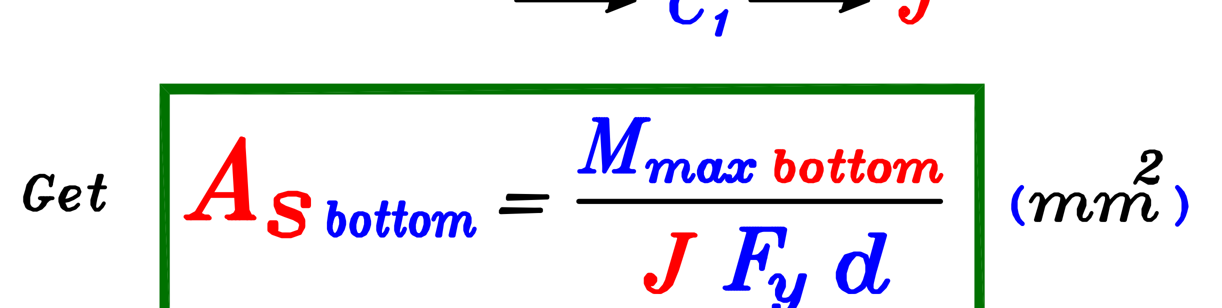
يوضع تسليح علوى ثانوى قيمته $5\phi 12/m'$



From $d = C_1 \sqrt{\dfrac{M_{max\ bottom}}{F_{cu} * B_{R.C.}}}$

$M_{max\ bottom}$ $t_{R.C.}$ $B_{R.C.}$

$\xrightarrow{Get} C_1 \longrightarrow J$



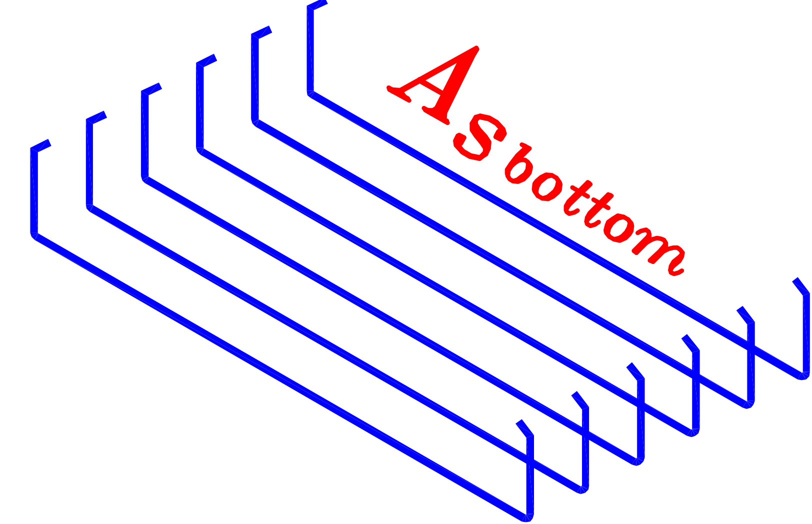
Check $A_{s\,min}$

$$A_{s\,min}\ (mm^2/m) = \begin{cases} 1.5\, d\ (mm) \\ 5\, \phi\, 12/m' \end{cases} \text{الأكبر}$$

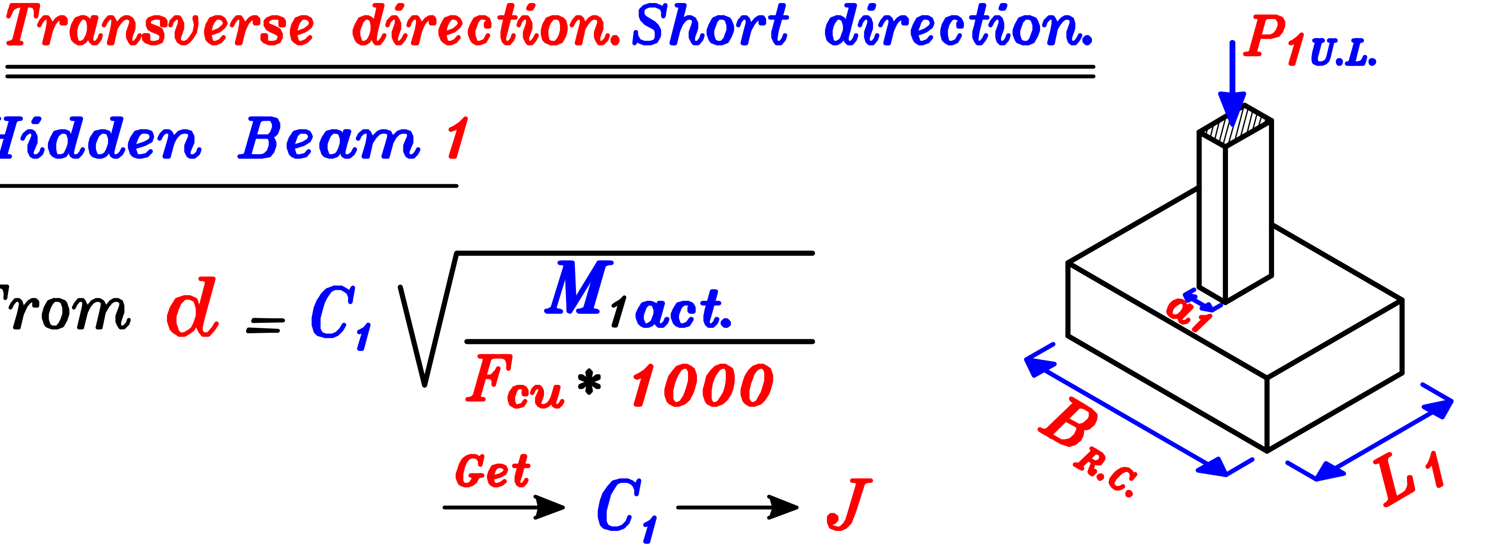
IF $A_{s\,bottom} \geq A_{s\,min} \longrightarrow$ o.k.

IF $A_{s\,bottom} < A_{s\,min} \longrightarrow$ Take $A_s = A_{s\,min}$

الحديد السفلى فى القواعد
يفضل أن يتم عمل ركبه من الجهتين

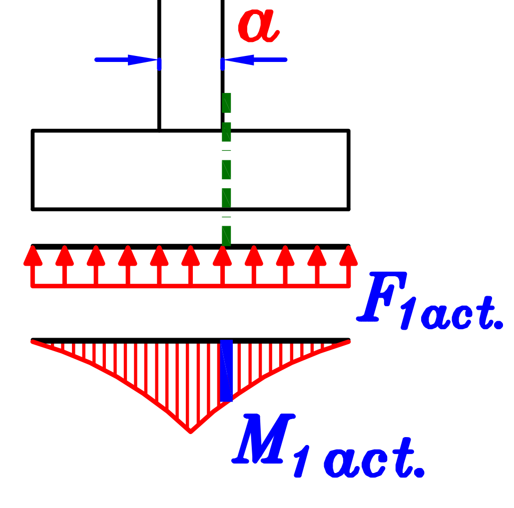


Hidden Beam 1



From $d = C_1 \sqrt{\dfrac{M_{1act.}}{F_{cu} * 1000}}$

$\xrightarrow{Get} C_1 \longrightarrow J$



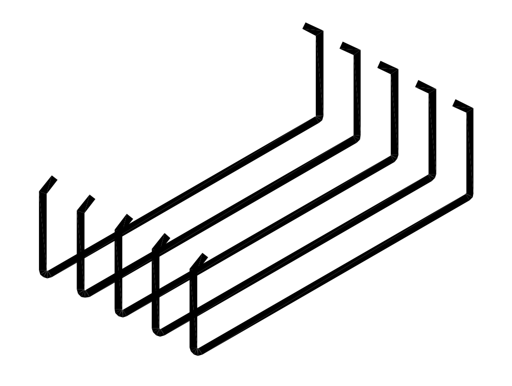
Get $$A_{s1} = \frac{M_{1act.}}{J\, F_y\, d} \quad (mm^2/m')$$

Check $A_{s\,min}$

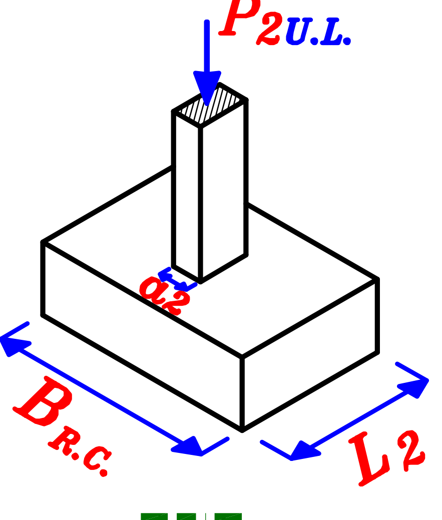
$$A_{s\,min} \; (mm^2/m) = \left\{ \begin{array}{l} 1.5\, d \; (mm) \\ 5 \phi 12 / m' \end{array} \right\} \text{الأكبر}$$

IF $A_{s1} \geqslant A_{s\,min} \longrightarrow$ o.k.

IF $A_{s1} < A_{s\,min} \longrightarrow$ Take $A_{s1} = A_{s\,min}$

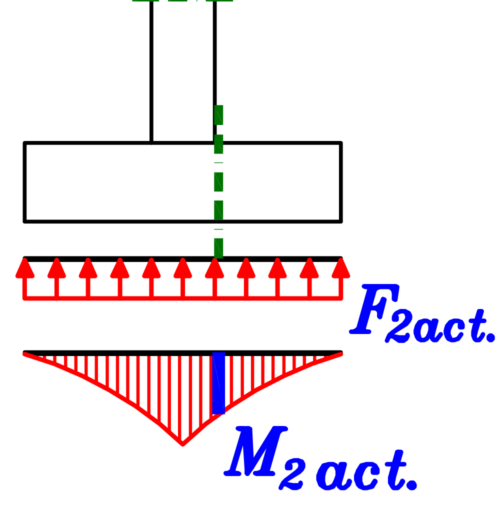


Hidden Beam 2



From $d = C_1 \sqrt{\dfrac{M_{2act.}}{F_{cu} * 1000}}$

$\xrightarrow{Get} C_1 \longrightarrow J$



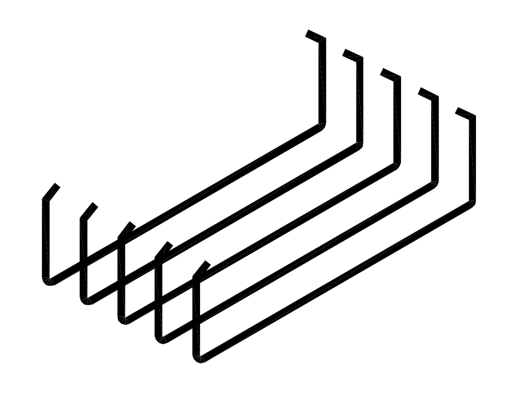
Get
$$A_{s2} = \frac{M_{2act.}}{J\, F_y\, d} \quad (mm^2/m')$$

Check $A_{s\,min}$

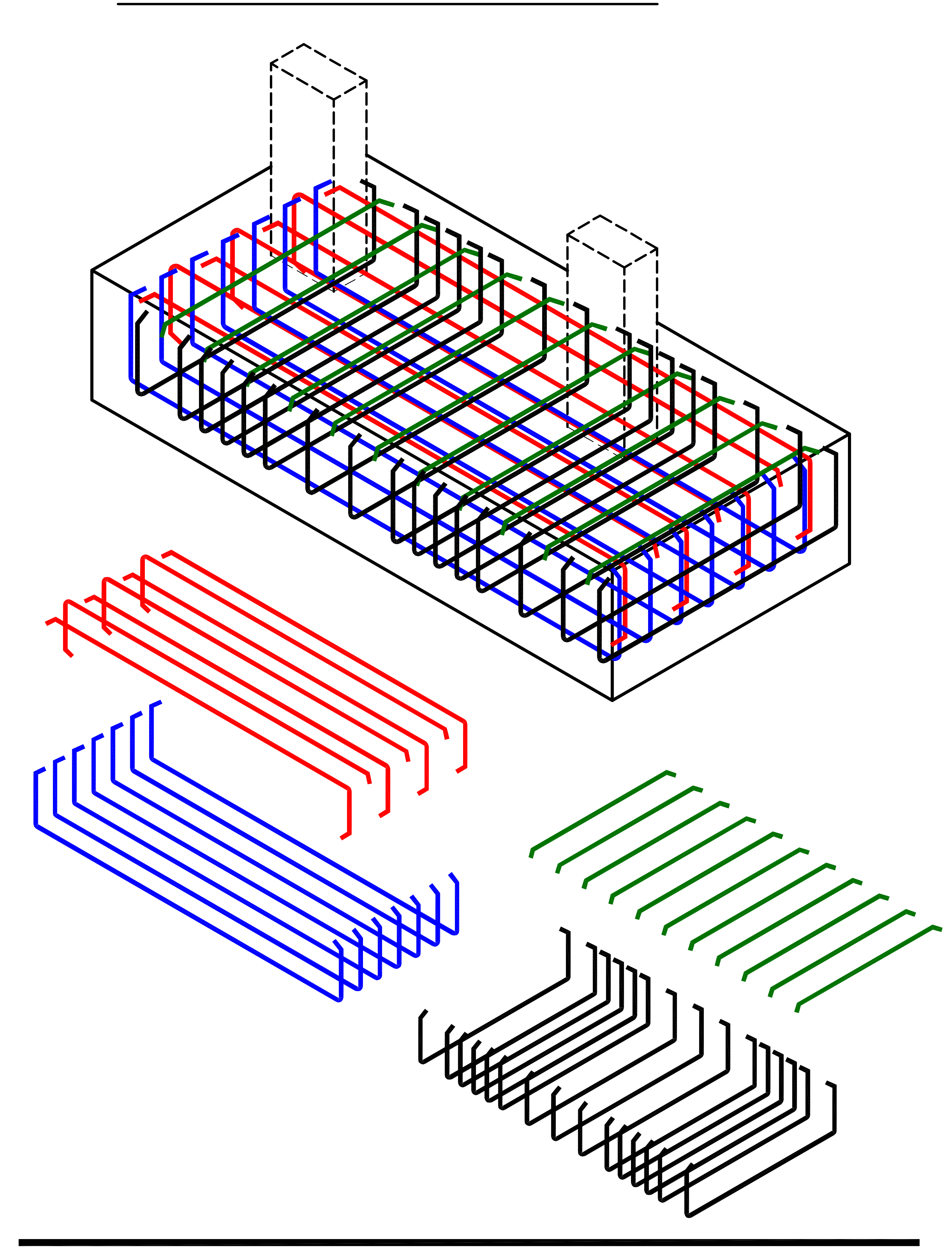
$$A_{s\,min}\ (mm^2/m) = \begin{cases} 1.5\, d\ (mm) \\ 5 \phi 12 / m' \end{cases} \text{الأكبر}$$

IF $A_{s2} \geq A_{s\,min} \longrightarrow$ o.k.

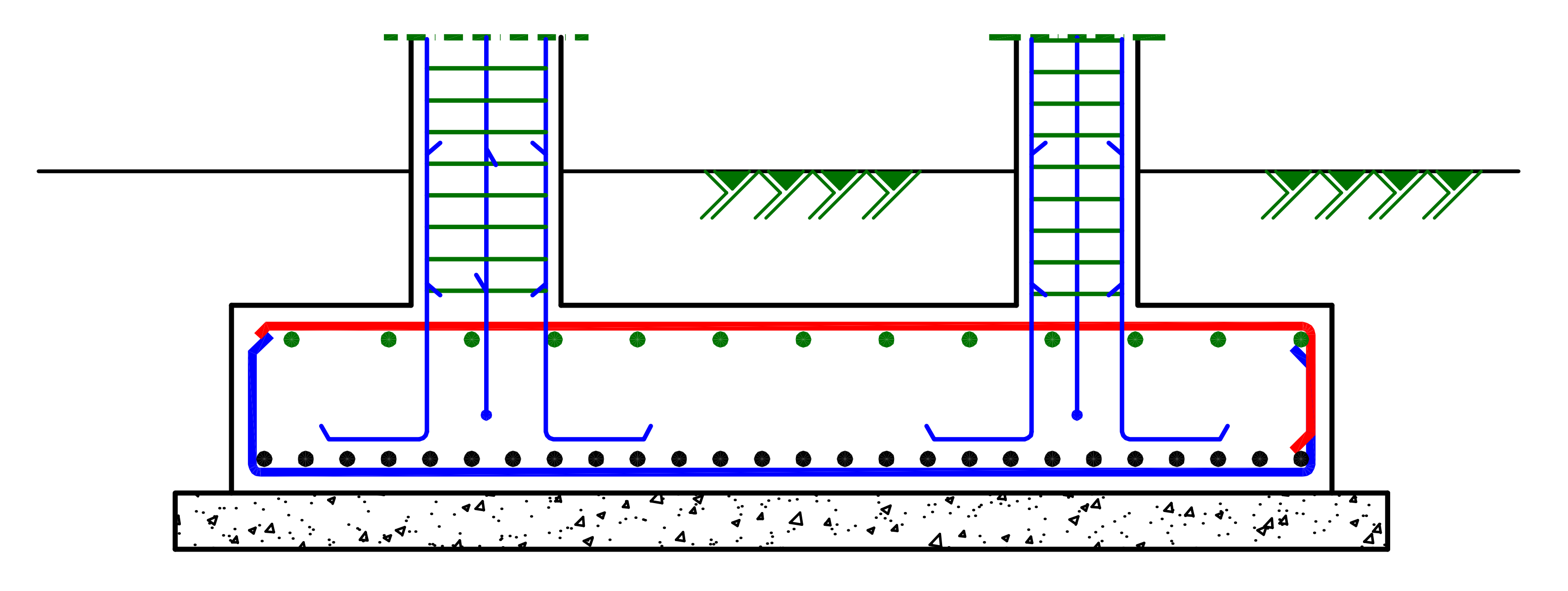
IF $A_{s2} < A_{s\,min} \longrightarrow$ Take $A_{s2} = A_{s\,min}$



6- Details of Reinforcement.



6- Details of Reinforcement.



Sec X-X

X X

A_{s2} A_{s2}

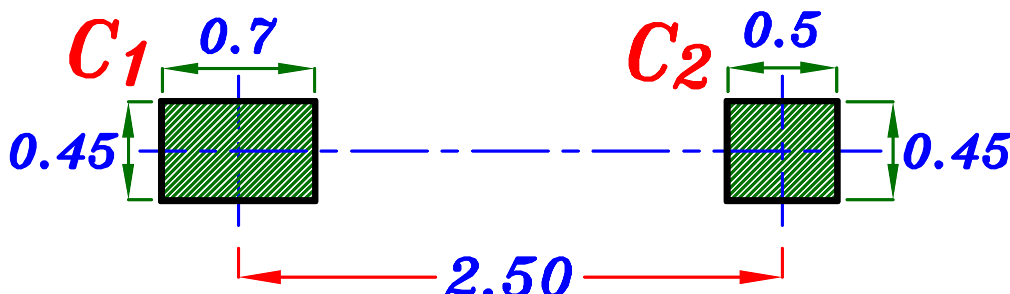
$5\phi12/m'$

L_1 L_2

Plan

Example.

It is required to design Footings to support a R.C. column C_1 (45 * 70) cm. and carrying working load 2400 kN and column C_2 (45 * 50) cm. and carrying working load 1800 kN the spacing between the C.L. of the two columns is 2.50 m as shown



and the allowable net bearing capacity in the Footing site is 150 kN/m^2. (F_{cu} = 25 N/mm^2, F_y = 360 N/mm^2).
and draw details of RFT. to scale 1:50

Solution.

Data given.

Column C_1 dimensions (450 * 700) mm

P_1 (working) = 2400 kN $\quad$ P_1 (U.L.) = 2400 * 1.5 = 3600 kN

Column C_2 dimensions (450 * 500) mm

P_2 (working) = 1800 kN $\quad$ P_2 (U.L.) = 1800 * 1.5 = 2700 kN

$R_{(working)} = P_1 + P_2 = 4200$ kN

$R_{(U.L.)} = 1.5 * 4200 = 6300$ kN

Bearing capacity of the soil = q_{all} = 150 kN/m^2

F_{cu} = 25 N/mm^2 $\quad$ F_y = 360 N/mm^2

Use Isolated Footing. First.

1- Calculate the Footing area. (Width & Length of R.C. Footing.)

Choose $t_{P.C.} = 30\ cm > 20\ cm$

Column. $C_1\ (450 * 700)\ mm$ P_1 (working) $= 2400\ kN$

$$L_{P.C.} - B_{P.C.} = b - a = 0.70 - 0.45 = 0.25\ m$$

$$L_{P.C.} = B_{P.C.} + 0.25\ m \quad \text{------} (1)$$

$$A_{P.C.} = \frac{P_w}{q_{all}} = \frac{2400\ (kN)}{150\ (kN/m^2)} = 16.0\ m^2$$

$$A_{P.C.} = B_{P.C.} * L_{P.C.} = 16.0\ m^2 \quad \text{-----} (2)$$

$$B_{P.C.} * L_{P.C.} = B_{P.C.} * (B_{P.C.} + 0.25) = 16.0\ m^2$$

$$B_{P.C.} = 3.87\ m$$

$B_{P.C.} = 3.90\ m$	$L_{P.C.} = 4.15\ m$
$B_{R.C.} = 3.30\ m$	$L_{R.C.} = 3.55\ m$

Column. $C_2\ (450 * 500)\ mm$ P_2 (working) $= 1800\ kN$

$$L_{P.C.} - B_{P.C.} = b - a = 0.50 - 0.45 = 0.05\ m$$

$$L_{P.C.} = B_{P.C.} + 0.05\ m \quad \text{------} (1)$$

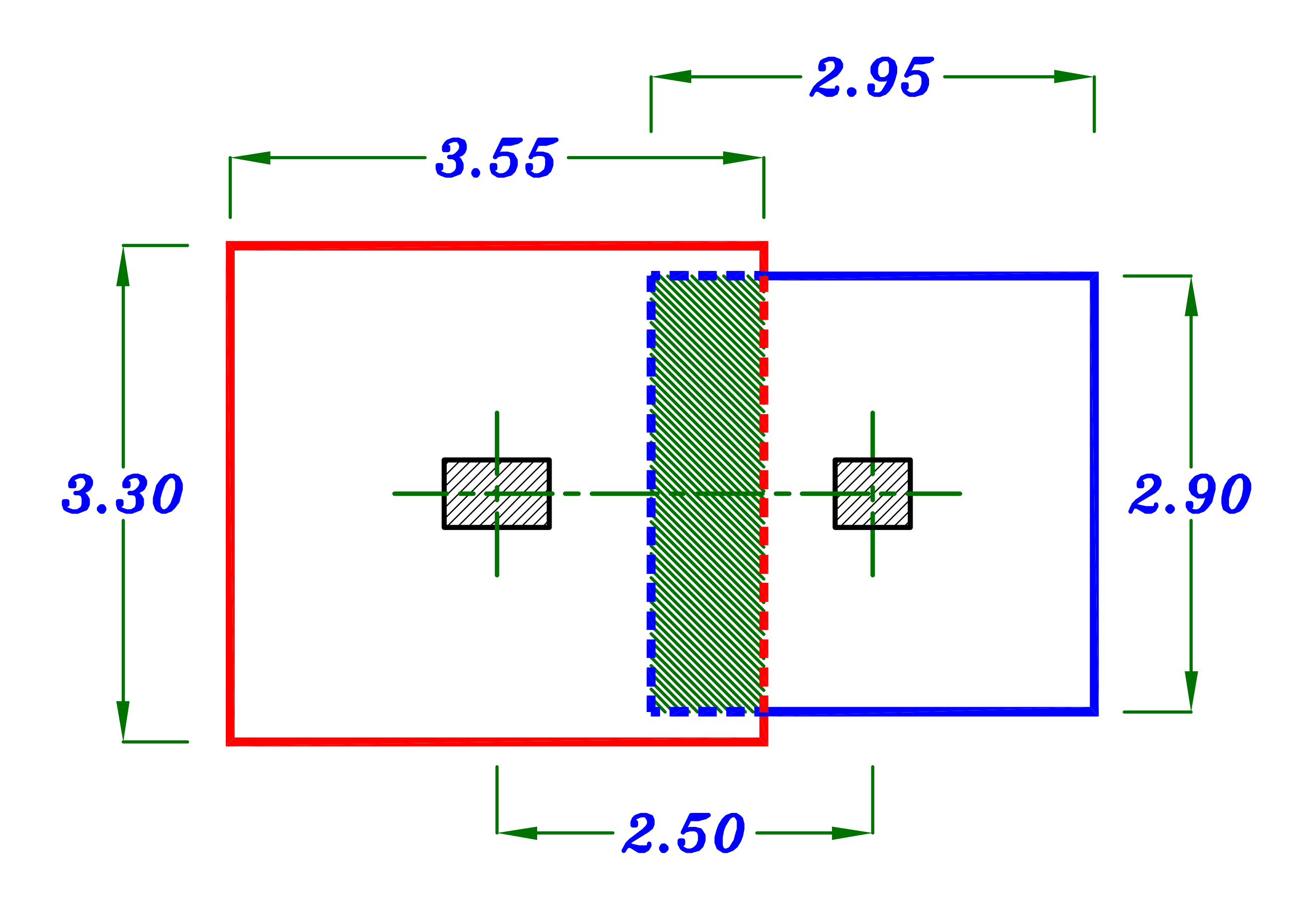
$$A_{P.C.} = \frac{P_w}{q_{all}} = \frac{1800\ (kN)}{150\ (kN/m^2)} = 12.0\ m^2$$

$$A_{P.C.} = B_{P.C.} * L_{P.C.} = 12.0 \ m^2 \quad \text{------} (2)$$

$$B_{P.C.} * L_{P.C.} = B_{P.C.} * (B_{P.C.} + 0.05) = 12.0 \ m^2$$

$$B_{P.C.} = 3.43 \ m$$

$B_{P.C.} = 3.50 \ m$	$L_{P.C.} = 3.55 \ m$
$B_{R.C.} = 2.90 \ m$	$L_{R.C.} = 2.95 \ m$



اذا استخدمنا قواعد منفصله سيحدث تداخل فى القواعد المسلحه
لذا سنحتاج لعمل قاعده واحده مشتركه . **Combined Footing**

Use Combined Footing.

1 – Calculate the Footing area. (Width & Length of R.C. Footing.)

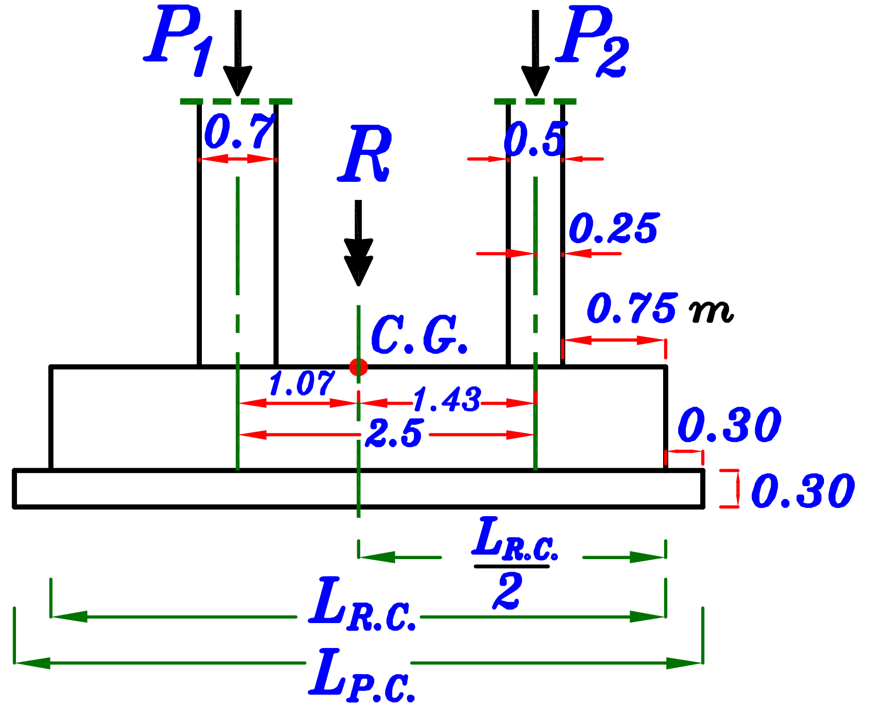
$R = 4200$ kN

$P_1 = 2400$ kN $\qquad P_2 = 1800$ kN

$2.5 - X \qquad X$

2.50

$$X = \frac{P_1}{R} * S = \frac{2400}{4200} * 2.5 = 1.43 \ m$$



$$\frac{L_{R.C.}}{2} = (X) + \frac{a_2}{2} + (0.50 \rightarrow 1.0) \ m$$

$$\frac{L_{R.C.}}{2} = (1.43) + \frac{0.5}{2} + 0.75 \longrightarrow L_{R.C.} = 4.86$$

$$L_{R.C.} = 4.90 \ m$$

$$L_{P.C.} = L_{R.C.} + 2\,t_{P.C.} = 4.90 + 2(0.3) = 5.50 \ m$$

$$L_{P.C.} = 5.50 \ m$$

Calculate the width of the Footing. B

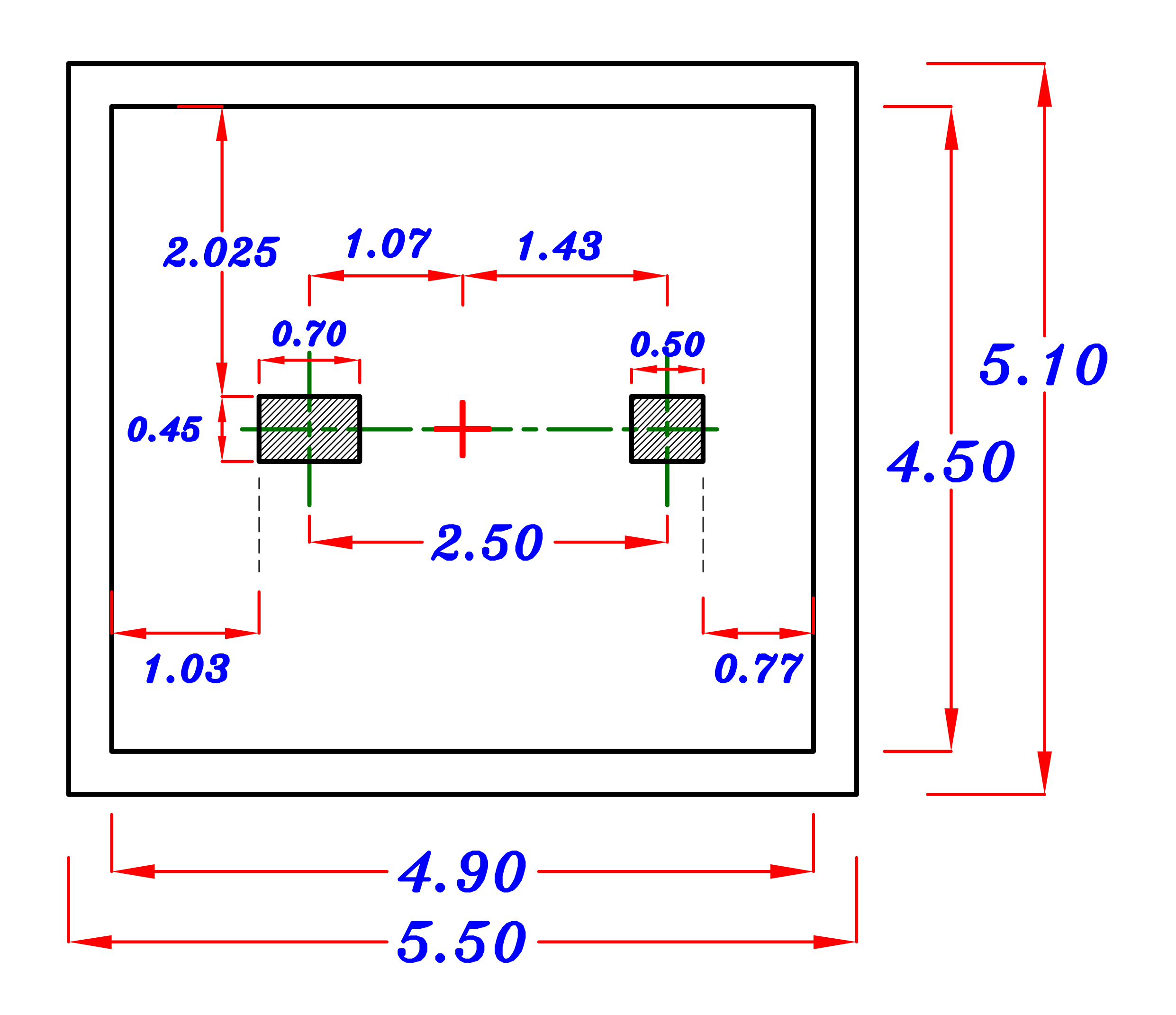
$$A_{P.C.} = \frac{R_w}{q_{all}} = \frac{4200}{150} = 28.0 \ m^2$$

$$A_{P.C.} = 28.0 = B_{P.C.} * L_{P.C.} = B_{P.C.} * 5.50 \longrightarrow B_{P.C.} = 5.09 \ m$$

$$B_{P.C.} = 5.10 \ m$$

$$B_{P.C.} = 5.10 \ m \qquad L_{P.C.} = 5.50 \ m$$

$$B_{R.C.} = 4.50 \ m \qquad L_{R.C.} = 4.90 \ m$$



2- Design the critical sections For moment.(Depth of R.C. Footing.)

- Actual Normal stress on R.C. Footing (U.L.)

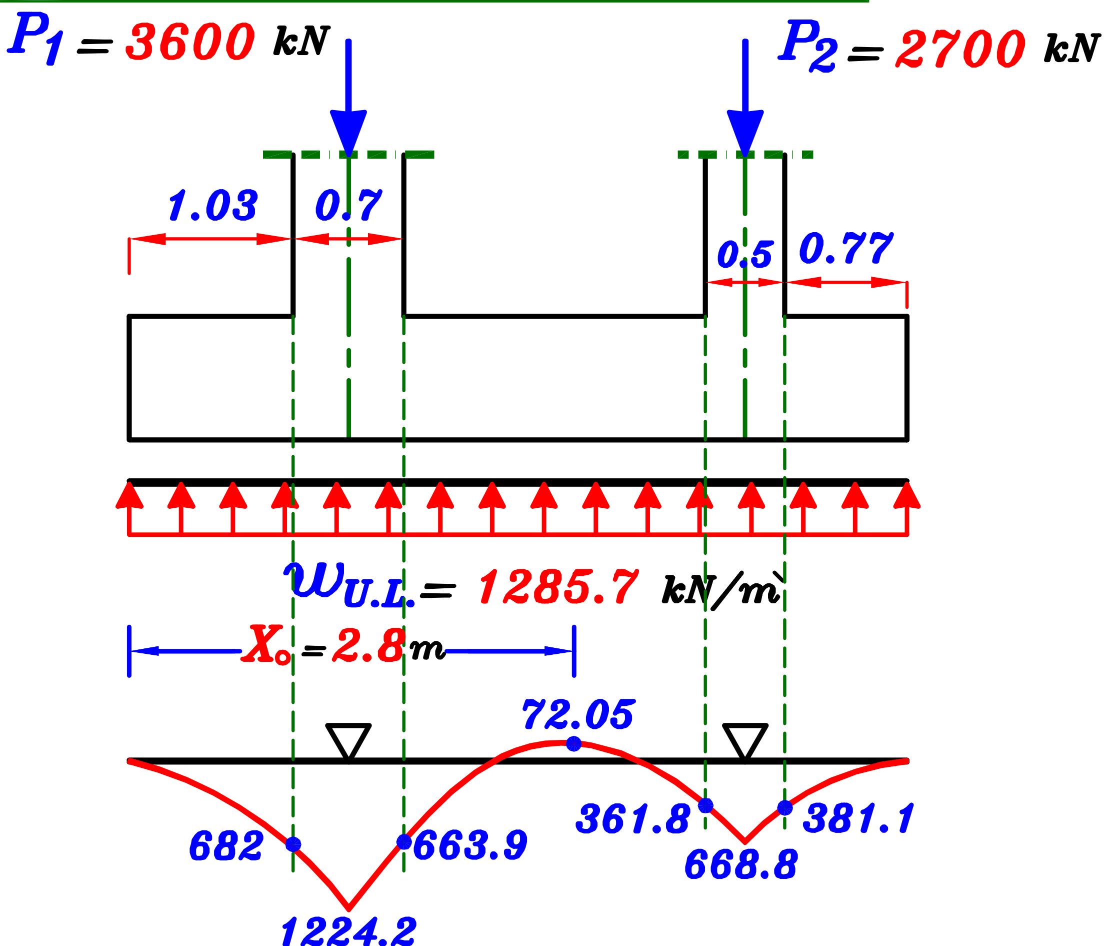
$$F_{act.} = \frac{R_{U.L.}}{B_{R.C.} * L_{R.C.}} = \frac{6300}{4.5 * 4.9} = 285.7 \ kN/m^2$$

- Actual Uniform Load on R.C. Footing (U.L.) as a beam.

$$W_{U.L.} = \frac{R_{U.L.}}{L_{R.C.}} = \frac{6300}{4.9} = 1285.7 \ kN/m'$$

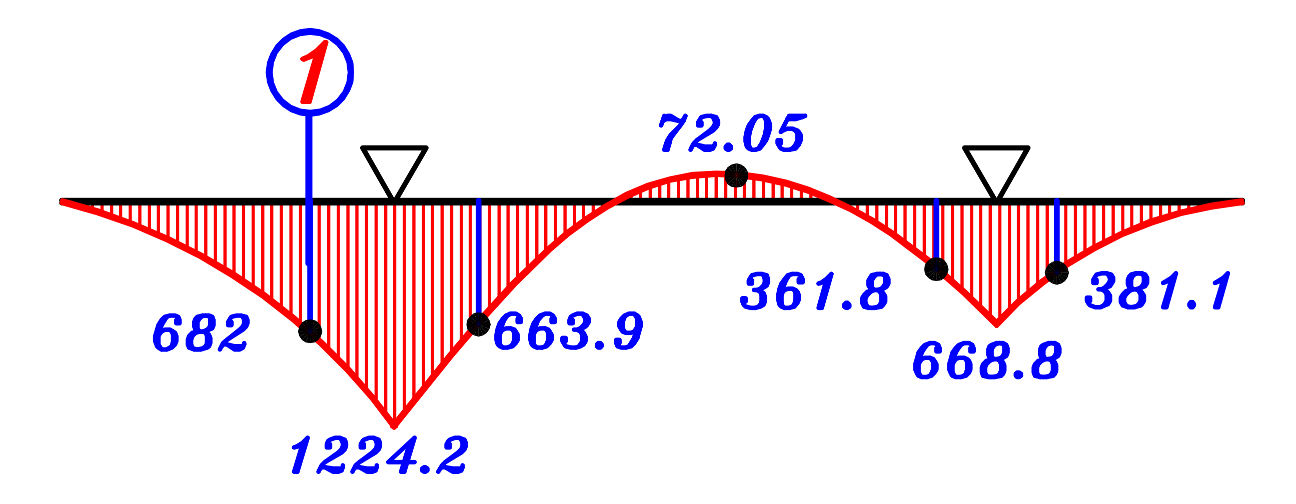
Drawing U.L. B.M.D. on all R.C. Footing. Longitudinal direction.

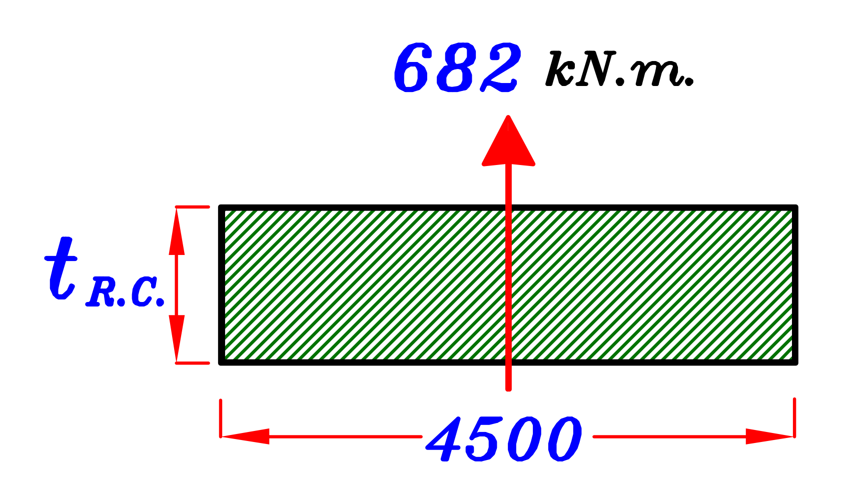
$$\text{Point of Zero Shear } (X_o) = \frac{3600}{1285.7} = 2.80 \ m$$

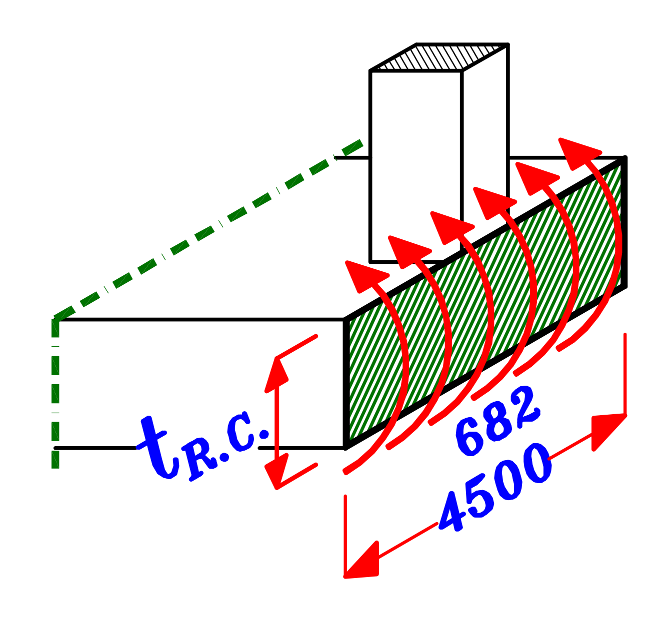


عند وش العمود

$$M_{max.} = 682 \quad kN.m$$







$$\because \; d = C_1 \sqrt{\frac{M_{act.}}{F_{cu} * b}}$$

Choose $C_1 = 5.0$

$$\therefore \; d = 5.0 \sqrt{\frac{682 * 10^6}{25 * 4500}} = 389.3 \text{ mm}$$

$$t_{R.C.} = d + 70 \text{ mm} = 389.3 + 70 = 459.3 \text{ mm}$$

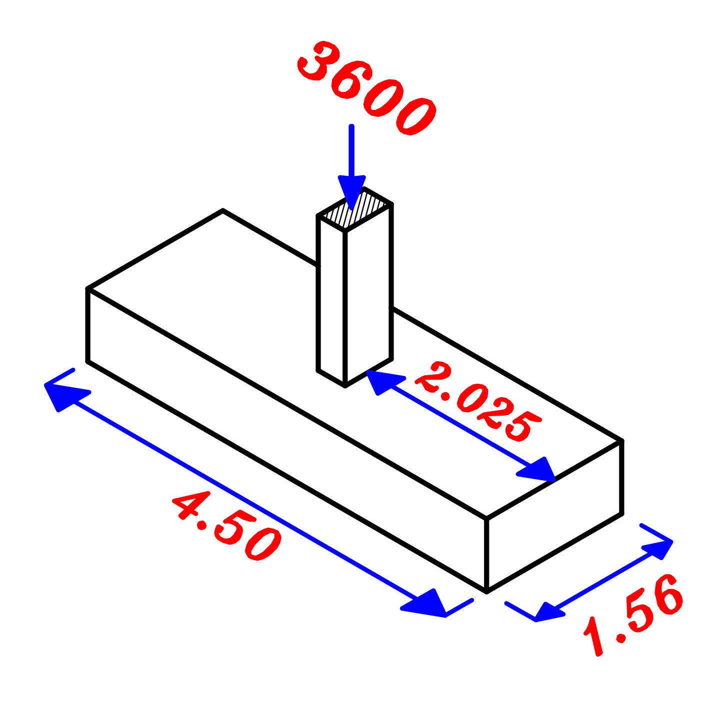
$$t_{R.C.} = 500 \text{ mm}$$

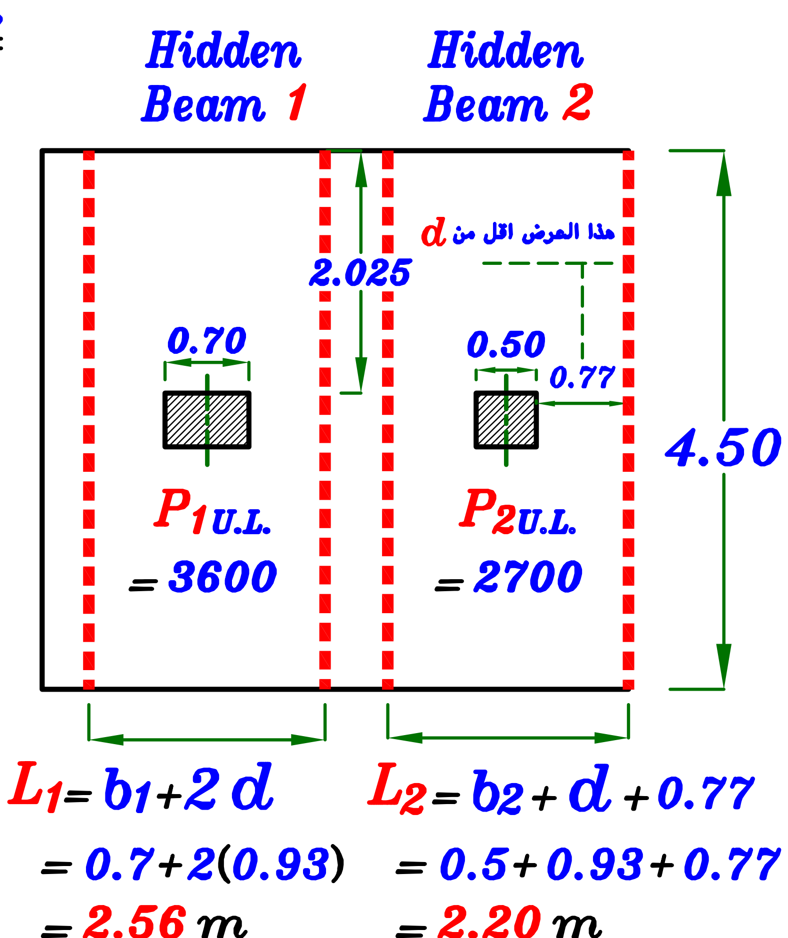
$$d = 430 \text{ mm}$$

Check depth in Transverse direction.

As a Hidden Beam.

Hidden Beam 1





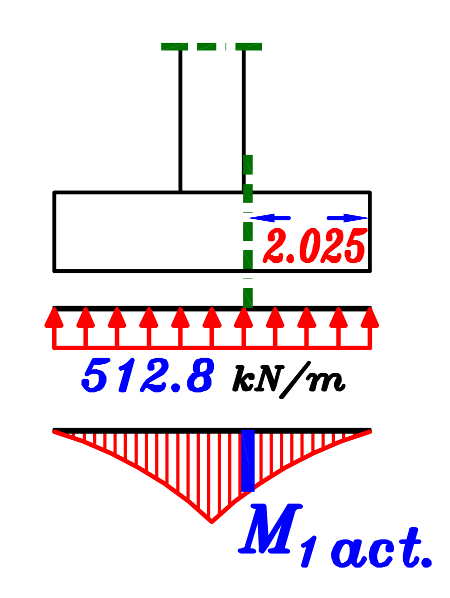
$$L_1 = b_1 + 2d = 0.7 + 2(0.93) = 2.56\ m$$

$$L_2 = b_2 + d + 0.77 = 0.5 + 0.93 + 0.77 = 2.20\ m$$

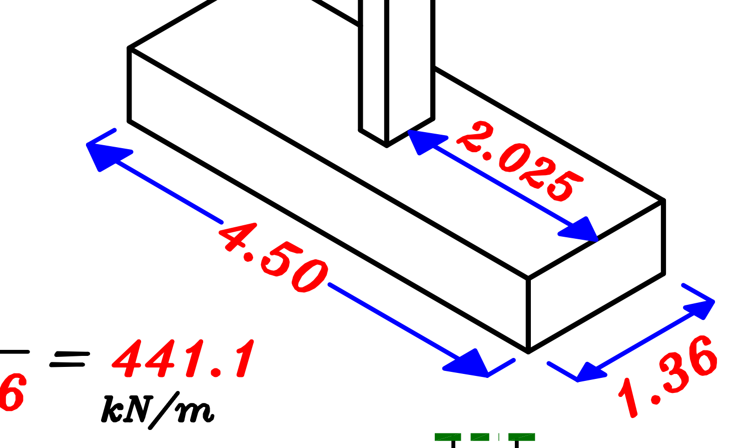
$$F_{1\,act.} = \frac{P_{1\,U.L.}}{B_{R.C.} * L_1} = \frac{3600}{4.5 * 1.56} = 512.8\ kN/m$$

$$M_{1\,act.} = (512.8 * 2.025 * 1.0\,m)\ \frac{2.025}{2}$$

$$M_{1\,act.} = 1051.4\ kN.m/m$$

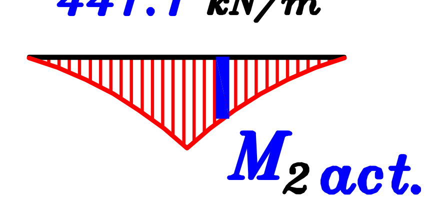


Hidden Beam 2



$$F_{2act.} = \frac{P_{2U.L.}}{B_{R.C.} * L_2} = \frac{2700}{4.5 * 1.36} = 441.1 \ kN/m$$

$$M_{2act.} = (441.1 * 2.025 * 1.0m) \frac{2.025}{2}$$



$$\boxed{M_{2act.} = 904.4 \ kN.m/m}$$

M_{bigger} From $M_{1act.}$ & $M_{2act.}$

$$\boxed{M_{bigger} = 1051.4 \ kN.m/m}$$

$$430 = C_1 \sqrt{\frac{1051.4 * 10^6}{25 * 1000}} \longrightarrow C_1 = 2.09 < 3.0$$

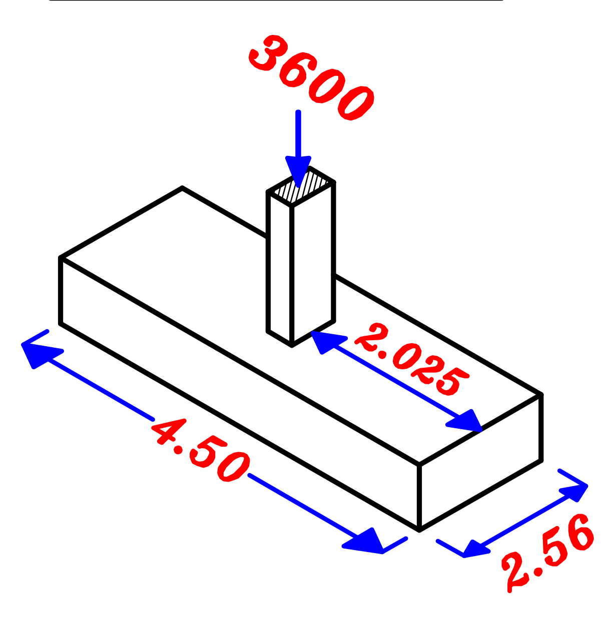
∴ **We have to increase the depth**

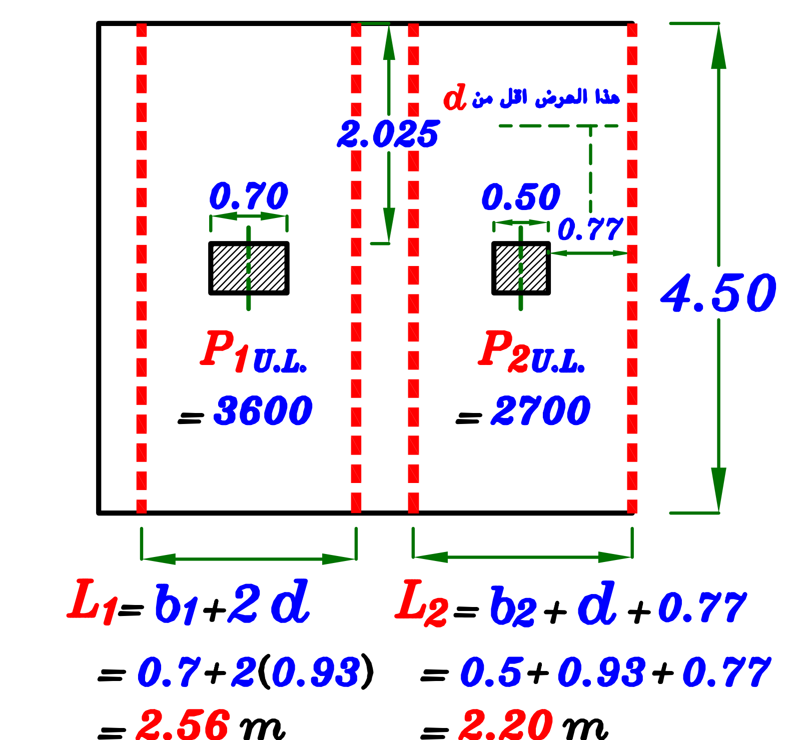
$$\therefore d = 4.5 \sqrt{\frac{1051.4 * 10^6}{25 * 1000}} = 922.8 \ mm$$

$$t_{R.C.} = d + 70 \ mm = 922.8 + 70 = 992.8 \ mm$$

$$\boxed{t_{R.C.} = 1000 \ mm} \qquad \boxed{d = 930 \ mm}$$

Hidden Beam 1





$L_1 = b_1 + 2\,d$
$= 0.7 + 2(0.93)$
$= 2.56\ m$

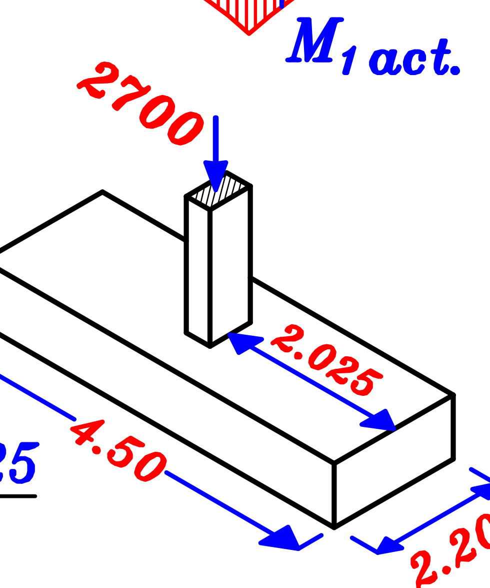
$L_2 = b_2 + d + 0.77$
$= 0.5 + 0.93 + 0.77$
$= 2.20\ m$

$$F_{1\,act.} = \frac{P_{1\,U.L.}}{B_{R.C.} * L_1}$$

$$= \frac{3600}{4.5 * 2.56} = 312.5\ kN/m$$

$$M_{1\,act.} = (312.5 * 2.025 * 1.0\,m)\ \frac{2.025}{2}$$

$$M_{1\,act.} = 640.7\ kN.m/m$$



Hidden Beam 2

$$F_{2act.} = \frac{P_{2\,U.L.}}{B_{R.C.} * L_2} = \frac{2700}{4.5 * 2.20} = 272.72\ kN/m$$

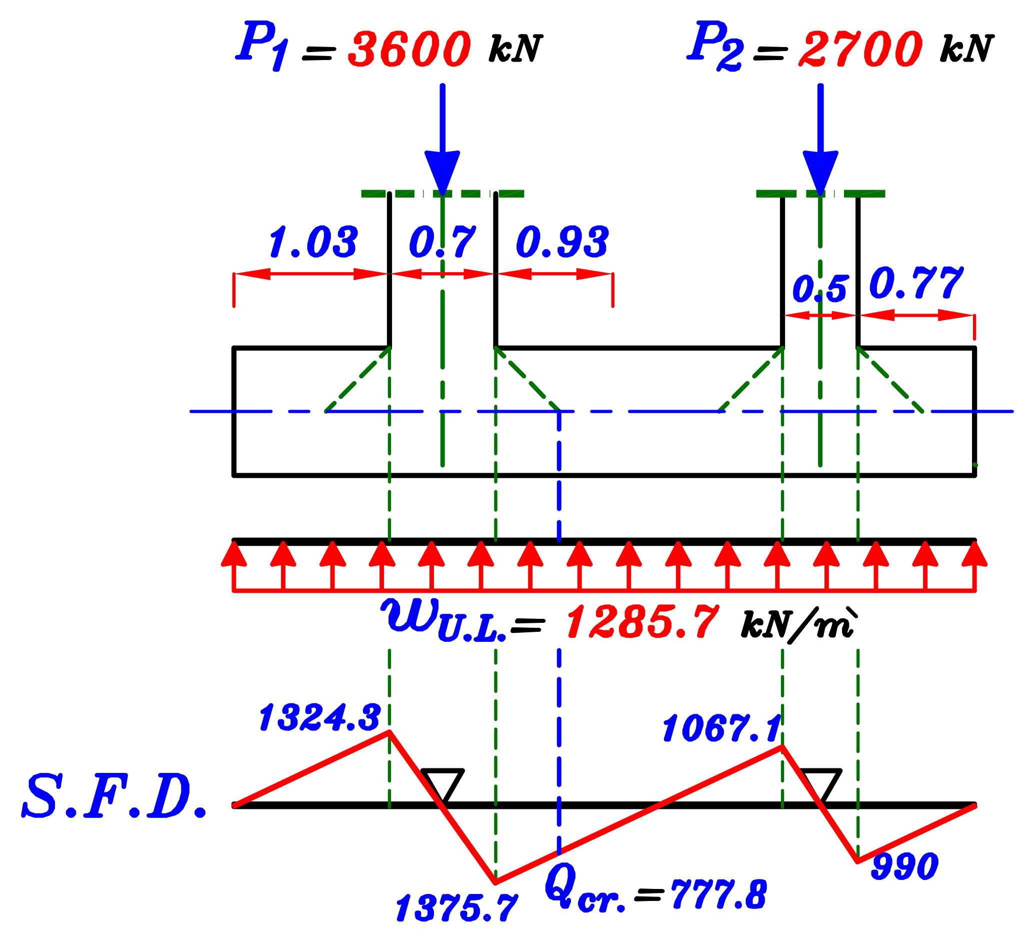


$$M_{2act.} = (272.72 * 2.025 * 1.0\,m)\ \frac{2.025}{2}$$

$$M_{2act.} = 559.16\ kN.m/m$$

3 – Check Shear at long direction

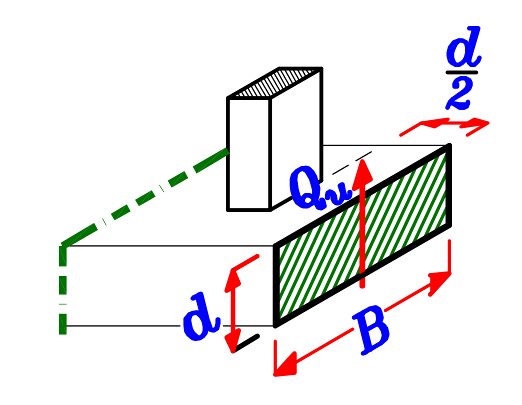
Critical section For Shear.



$$Q_{cr.} = Q_{max.} - w_{U.L.} * \frac{d}{2} = 1375.7 - 1285.7 * \frac{0.93}{2} = 777.8 \text{ kN}$$

* Calculate Actual shear stress. (q_u)

$$q_u = \frac{Q_{cr.}}{B * d} = \frac{777.8 * 10^3}{4500 * 930} = 0.186 \text{ kN/m}^2$$



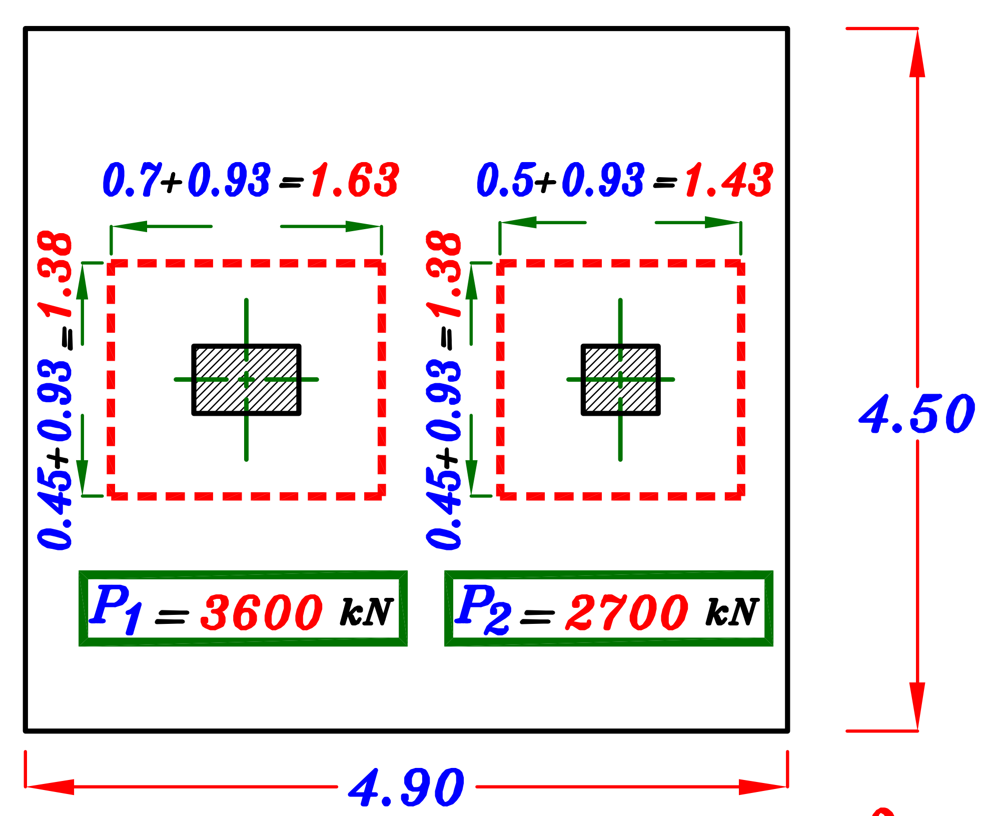
* Allowable shear stress. (q_{su})

$$q_{su} = 0.16\sqrt{\frac{F_{cu}}{\gamma_c}} = 0.16\sqrt{\frac{25}{1.5}} = 0.653 \text{ N/mm}^2$$

$q_u < q_{su}$ ⟶ Safe shear stresses

No need to increase dimensions.

4- Check Punching Shear. • القص الثاقب

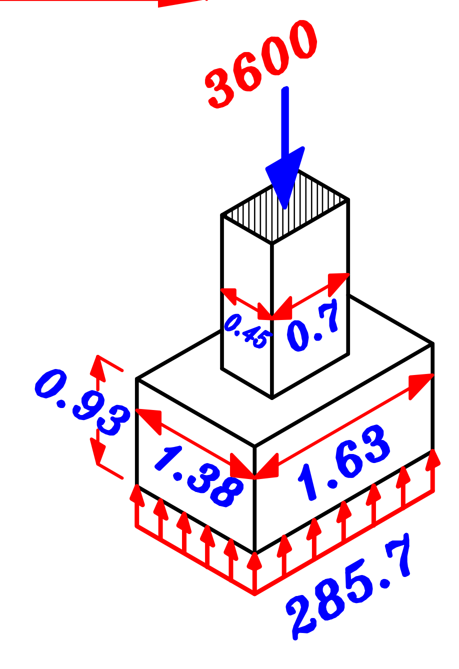


Column 1

* Calculate Punching Force. (Q_{1p})

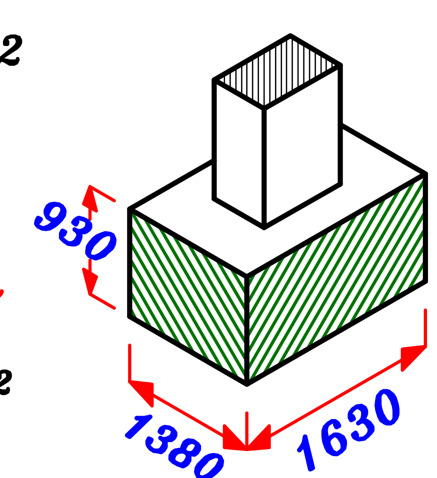
$$Q_{1p} = 3600 - 285.7 \ (1.38 * 1.63)$$

$$= 2957.3 \ kN$$



$$A_{1p} = [2(1380) + 2(1630)] * 930$$

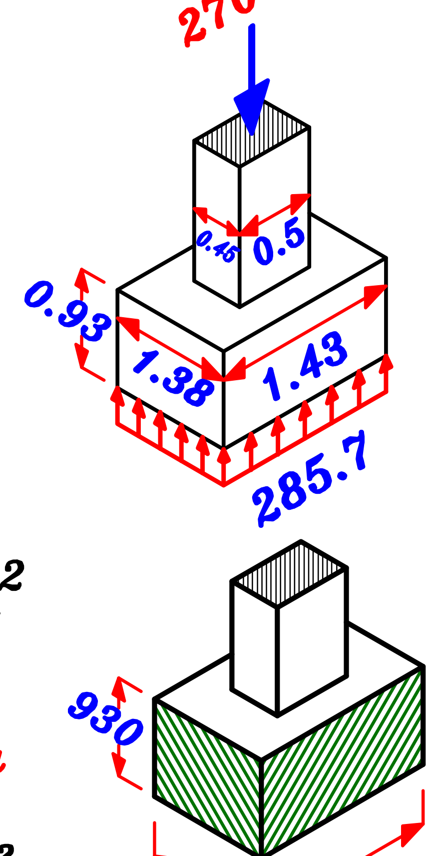
$$= 5598600 \ mm^2$$



* Calculate Actual Punching shear stress. q_{1pu}

$$q_{1pu} = \frac{2957.3 * 10^3}{5598600} = 0.528 \ N/mm^2$$

Column 2



* Calculate Punching Force. (Q_{2p})

$$Q_{2p} = 2700 - 285.7\ (1.38 * 1.43)$$

$$= 2136.2\ kN$$

$$A_{2p} = [2(1380) + 2(1430)] * 930$$

$$= 5226600\ mm^2$$

* Calculate Actual Punching shear stress. q_{1pu}

$$q_{2pu} = \frac{2136.2 * 10^3}{5226600} = 0.408\ N/mm^2$$

$q_{pu_{max}}$ the bigger q_{1pu} & q_{2pu} $= 0.528\ N/mm^2$

---

* Calculate allowable Punching shear stress. $q_{p_{cu}}$

نأخذ القيمه الاقل من الاربع قيم التاليه .

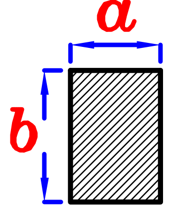
$$q_{pcu} = 0.8\left(\frac{\alpha\, d}{b_o} + 0.2\right)\sqrt{\frac{F_{cu}}{\gamma_c}}$$

$\alpha = 4$ Interior Col.

$$b_o = 2(a+d) + 2(b+d) = 2(450+930) + 2(700+930) = 6020\ mm$$

$$q_{pcu} = 0.8\left(\frac{4 * 930}{6020} + 0.2\right)\sqrt{\frac{25}{1.5}} = 2.67\ N/mm^2$$

$$q_{pcu} = 0.316\left(0.5 + \frac{a}{b}\right)\sqrt{\frac{F_{cu}}{\gamma_c}} \quad (N/mm^2)$$



$a = 0.45\ m\ ,\ b = 0.70\ m$

$$q_{pcu} = 0.316\left(0.5 + \frac{0.45}{0.70}\right)\sqrt{\frac{25}{1.5}} = 1.47 \quad N/mm^2$$

$$q_{pcu} = 0.316\sqrt{\frac{F_{cu}}{\gamma_c}} = 0.316\sqrt{\frac{25}{1.5}} = 1.29\ N/mm^2$$

$$q_{pcu} = 1.60 \quad (N/mm^2)$$

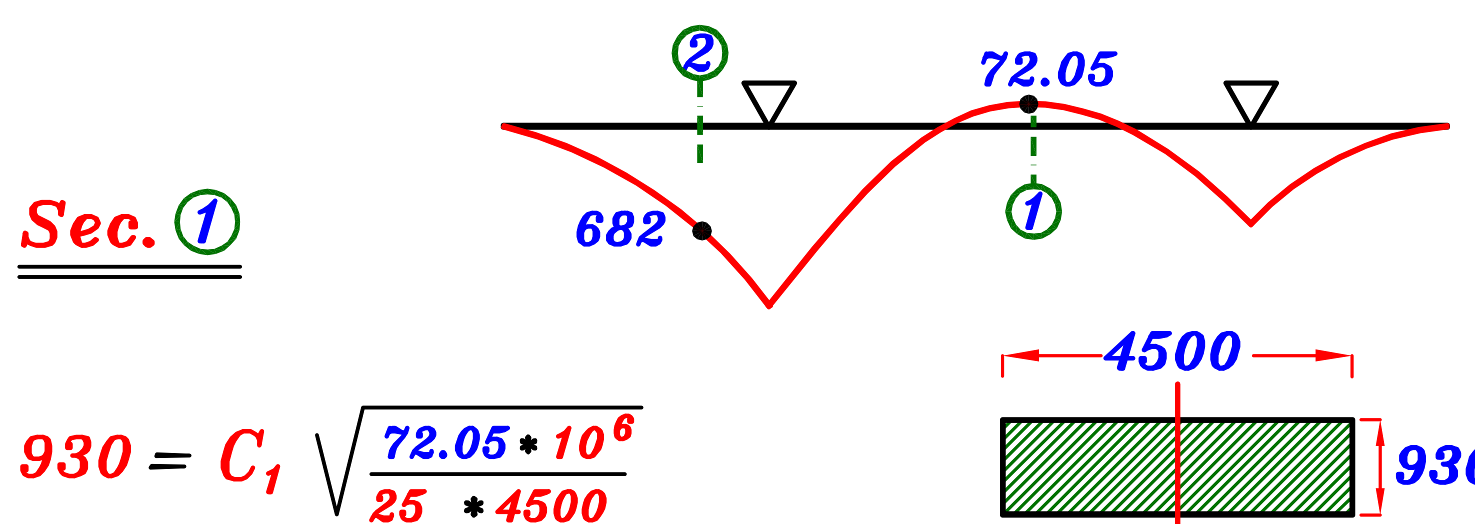
$\therefore$ $q_{pcu} = 1.29 \quad N/mm^2$ نأخذ القيمة الاقل من الاربع قيم السابقة .

$$q_{pu_{max}} = 0.528\ N/mm^2$$

$q_{pu} \leqslant q_{p\,cu}$ $\longrightarrow$ **Safe punching shear.** No need to increase dimensions.

5- Reinforcement of the Footing.

Longitudinal direction.



Sec. 1

$$930 = C_1 \sqrt{\frac{72.05 * 10^6}{25 \; * 4500}}$$

72.05 kN.m

$$\longrightarrow C_1 = 36.7 \longrightarrow J = 0.826$$

$$A_s = \frac{M_{act.}}{J \, F_y \, d} = \frac{72.05 * 10^6}{0.826 * 360 * 930} = 260.53 \; mm^2$$

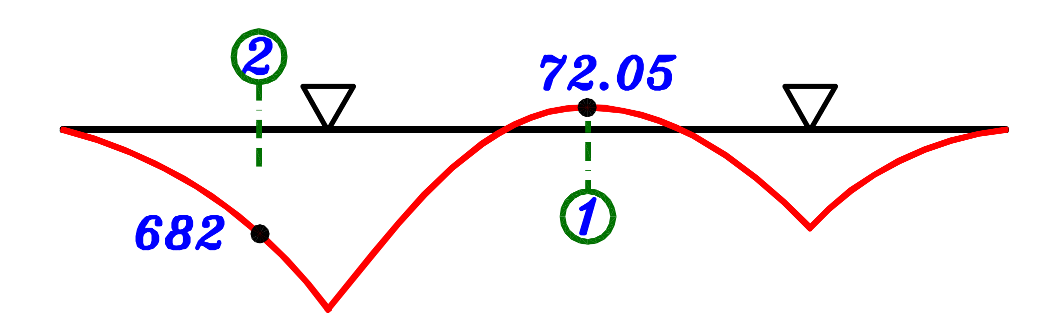
$$A_s \; (mm^2/m) = \frac{A_s}{B_{R.C.}} = \frac{260.53}{4.50} = 57.9 \; mm^2/m'$$

Check $A_{s\,min}$

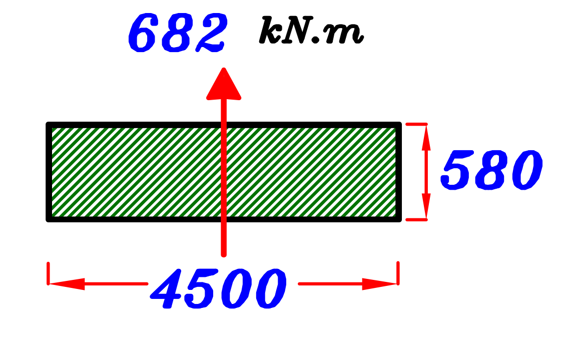
$$A_{s\,min} = \left\{ \begin{array}{l} 1.5\,d = 1.5 * 930 = 1395 \\ 5 \phi 12/m' = 565.5 \end{array} \right\} 1395 \; mm^2$$

$$\therefore A_s < A_{s\,min} \longrightarrow \text{Take } A_s = 1395 \; mm^2$$

$$\boxed{7 \phi 16/m'}$$



Sec. ②



$$930 = C_1 \sqrt{\frac{682 * 10^6}{25 * 4500}}$$

$\longrightarrow C_1 = 11.9 \longrightarrow J = 0.826$

$$A_s = \frac{M_{act.}}{J\, F_y\, d} = \frac{682 * 10^6}{0.826 * 360 * 930} = 2466.1 \ mm^2$$

$$A_s \ (mm^2/m) = \frac{A_s}{B_{R.C.}} = \frac{2466.1}{4.50} = 548.0 \ mm^2/m`$$

Check $A_{s\,min}$

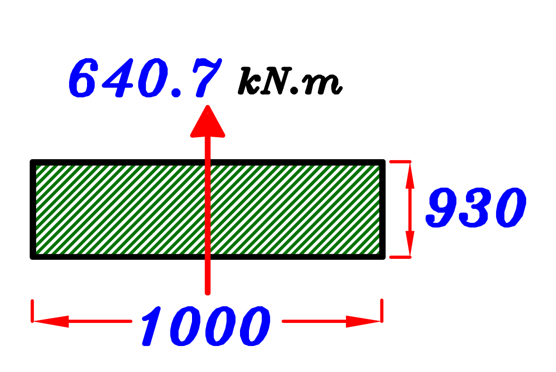
$$A_{s\,min} = \left\{ \begin{array}{l} 1.5\, d = 1.5 * 930 = 1395 \\ 5 \phi 12 / m` = 565.5 \end{array} \right\} 1395 \ mm^2$$

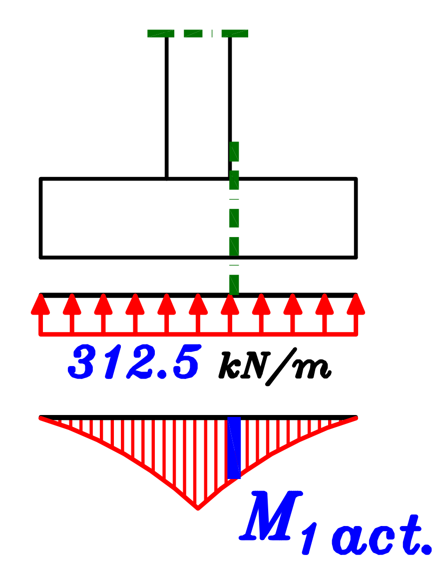
$\therefore A_s < A_{s\,min} \longrightarrow$ Take $A_s = 1395 \ mm^2$

$7 \phi 16 / m`$

Hidden Beam 1

$$M_{1act.} = 640.7 \; kN.m/m$$





$$930 = C_1 \sqrt{\frac{640.7 * 10^6}{25 * 1000}} \longrightarrow C_1 = 5.81 \longrightarrow J = 0.826$$

$$A_s = \frac{M_{act.}}{J \, F_y \, d} = \frac{640.7 * 10^6}{0.826 * 360 * 930} = 2316.8 \; mm^2/m`$$

Check $A_{s_{min}}$

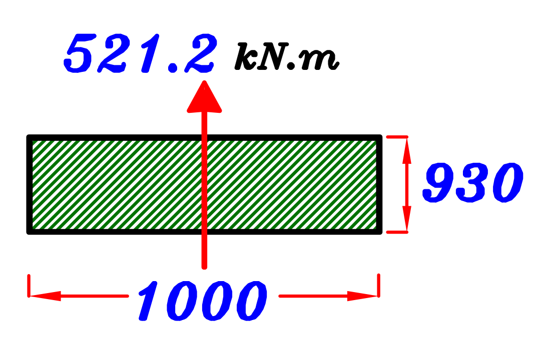
$$A_{s_{min}} = \begin{cases} 1.5\,d = 1.5 * 930 = 1395 \\ 5 \phi 12/m` = 565.5 \end{cases} 1395 \; mm^2$$

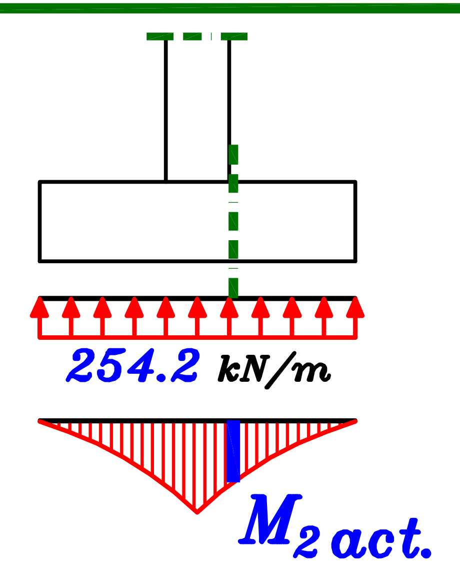
$$\therefore A_s > A_{s_{min}} \longrightarrow o.k.$$

$$A_s = 2316.8 \; mm^2 \qquad \boxed{7 \phi 22/m`}$$

Hidden Beam 2

$$M_{2act.} = 521.2 \ kN.m/m$$





$$930 = C_1 \sqrt{\frac{559.16 * 10^6}{25 \ * 1000}} \longrightarrow C_1 = 6.44 \longrightarrow J = 0.826$$

$$A_s = \frac{M_{act.}}{J \ F_y \ d} = \frac{559.16 * 10^6}{0.826 * 360 * 930} = 2021.9 \ mm^2/m'$$

Check $A_{s_{min}}$

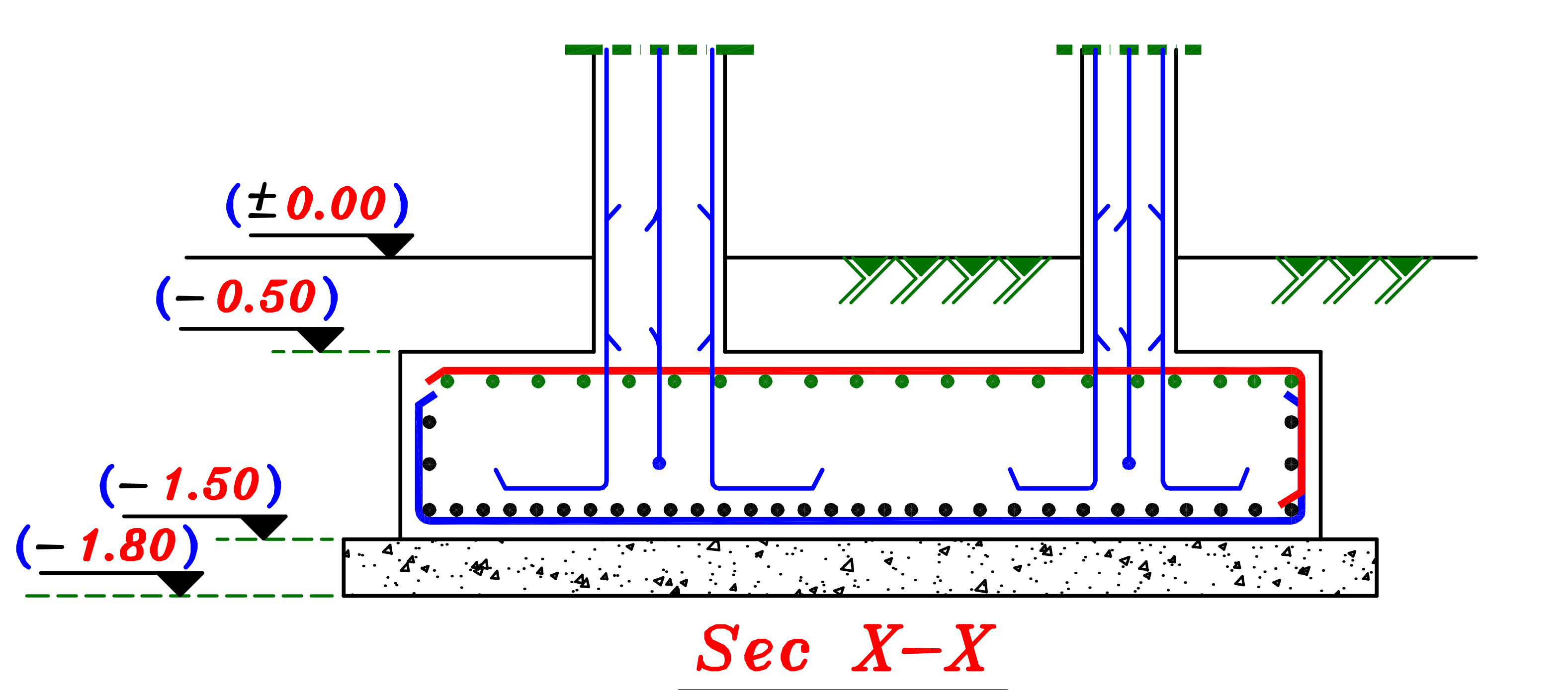
$$A_{s_{min}} = \left\{ \begin{array}{l} 1.5\,d = 1.5 * 930 = 1395 \\ 5 \phi 12/m' = 565.5 \end{array} \right\} 1395 \ mm^2$$

$$\therefore \ A_s > A_{s_{min}} \longrightarrow o.k.$$

$$A_s = 2021.9 \ mm^2$$

$6 \phi 22/m'$

6- Details of Reinforcement.



Sec X–X

7ϕ16/m'

5ϕ12/m'

7ϕ22/m'

5ϕ12/m'

6ϕ22/m'

7ϕ16/m'

5.10

4.50

X

X

2.68

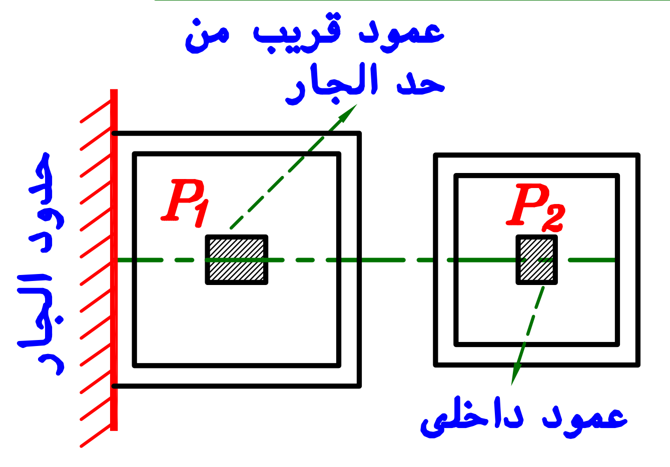
2.22

4.90

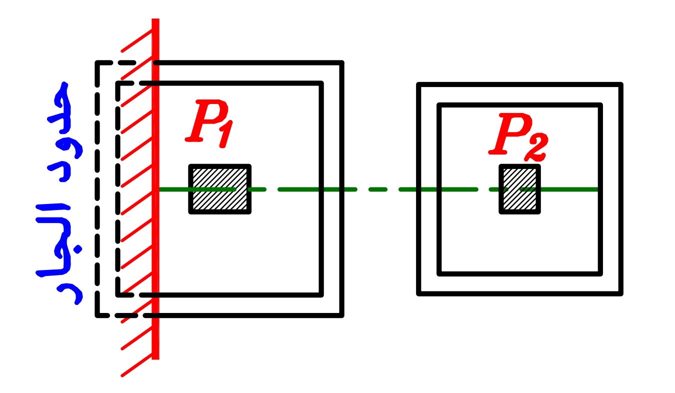
5.50

تصميم القواعد بجوار حد الجار .

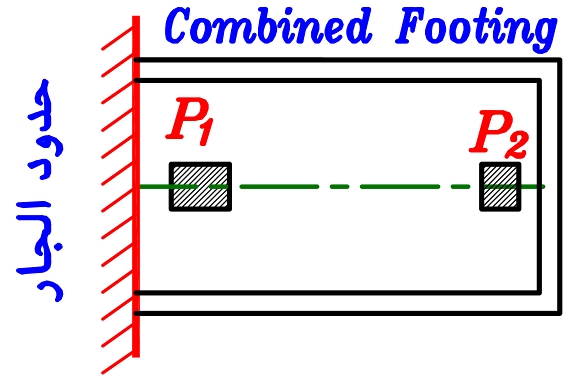
يتم عمل قواعد لاعمده حد الجار فى احدى الحالتان التاليتان :-

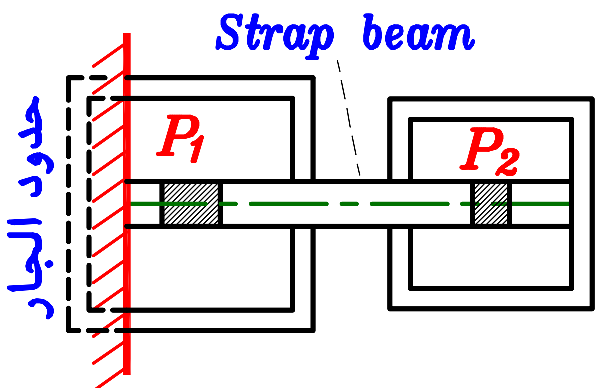


١- عند وجود عمود قريب من حد الجار نحاول أولا أن نعمل قاعده منفصله بأبعاد خاصه بحيث لا تدخل القاعده العاديه فى حدود الجار .

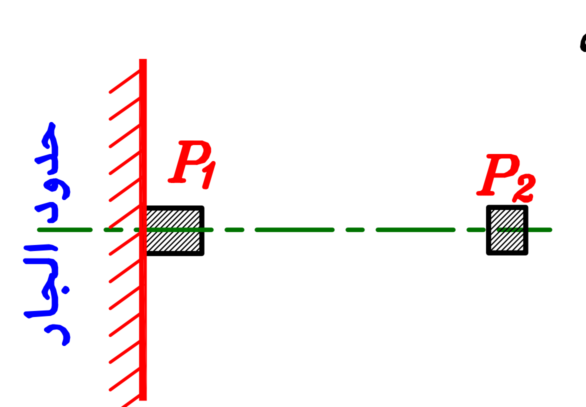


و لكن اذا زادت أبعاد القاعده و تعدت حدود الجار فيتم ربط عمود الجار بعمود داخلى مجاور اما عن طريق قاعده مشتركه
Combined Footing
أو كمره كبيره للتحزيم
Strap beam

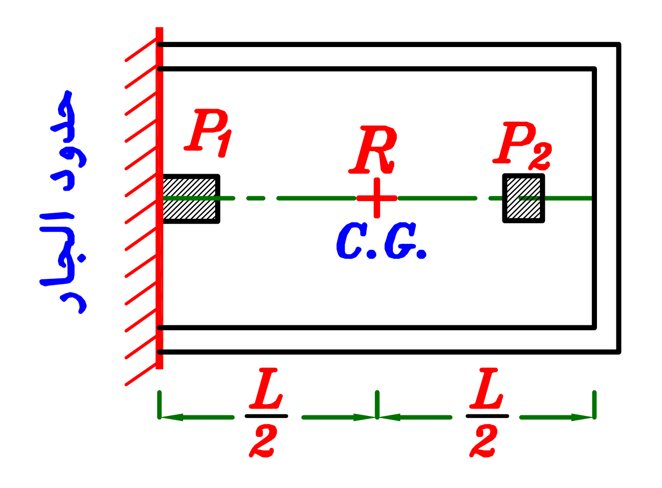




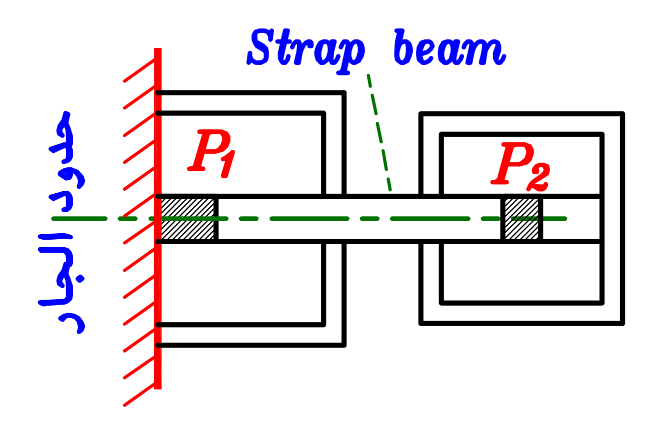
٢ـ عند وجود عمود عند حد الجار مباشره يتم ربط عمود الجار بعمود داخلى مجاور له



اما عن طريق قاعده مشتركه
Combined Footing
بحيث يكون مكان محصله الاحمال هو نفس مكان *C.G.* القاعده



أو كمره كبيره للتحزيم
Strap beam



و يتوقف اختيار نوع القاعده التى سوف تربط عمود حد الجار بالعمود الداخلى على :

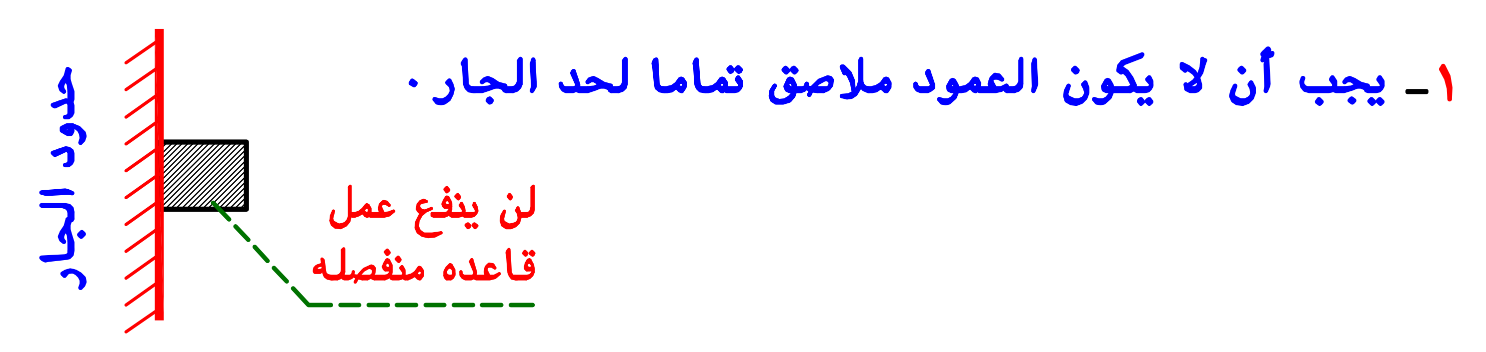
١ـ المسافه بين عمود حد الجار و العمود الداخلى المجاور . C_1 , C_2

٢ـ قيمة الاحمال الواقعه على العمودين . P_1 , P_2

٣ـ أكبر اجهاد تتحمله التربة *Bearing capacity of soil*

الحالات التى يمكن استخدام قاعده منفصله لعمود عند حد الجار .

١- يجب أن لا يكون العمود ملاصق تماما لحد الجار .



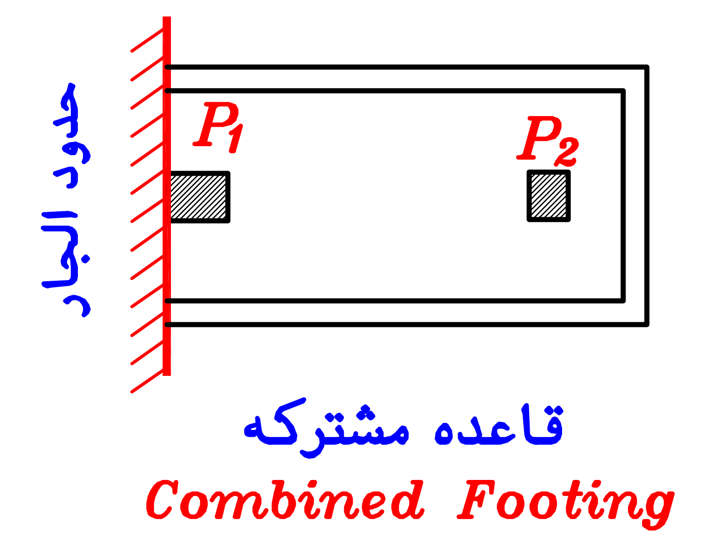
٢- يجب أن لا تقل المسافه من ($C.L.$) العمود

الى حد الجار مسافه (D)

$$D > \frac{1}{2}\sqrt{\frac{P_{col.}}{q_{all}}}$$

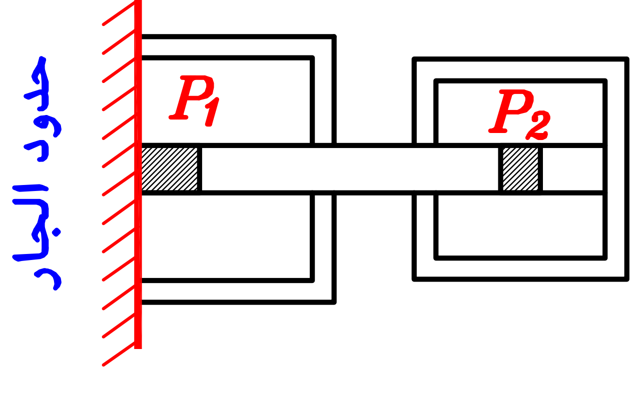
اذا لم تتحقق هذه الشروط لن نستطيع عمل قاعده منفصله

و نضطر لربط هذا العمود بالعمود الداخلى المجاور له



قاعده مشتركه

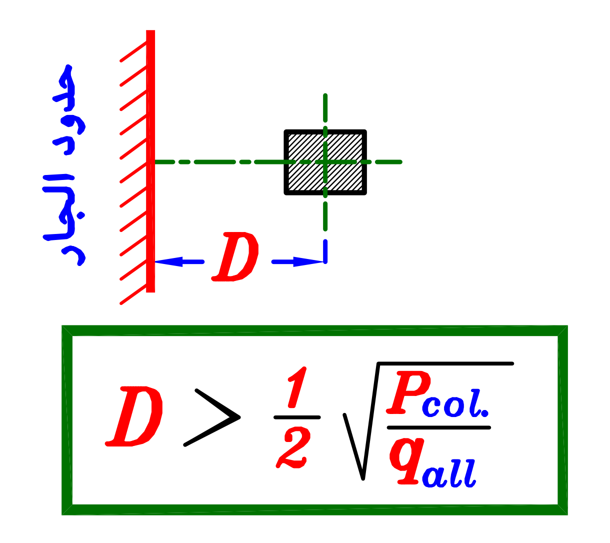
Combined Footing



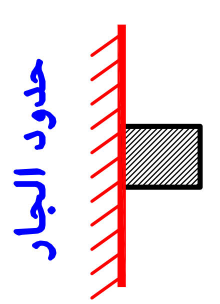
Strap beam

1- Strap Beam. كمره تحزيم

اذا لم ينفع حل القواعد المنفصله لوجود احدى الاسباب التاليه .



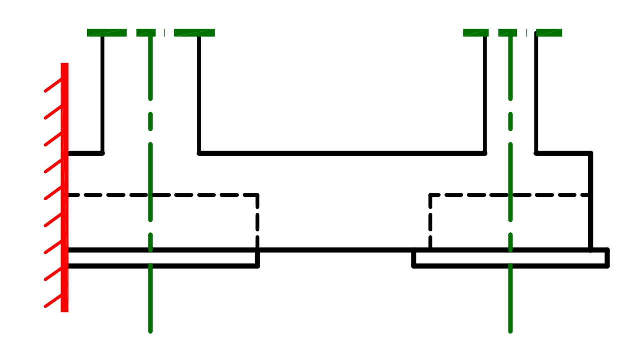
$$D > \frac{1}{2}\sqrt{\frac{P_{col.}}{q_{all}}}$$



العمود ملاصق تماما لحد الجار .

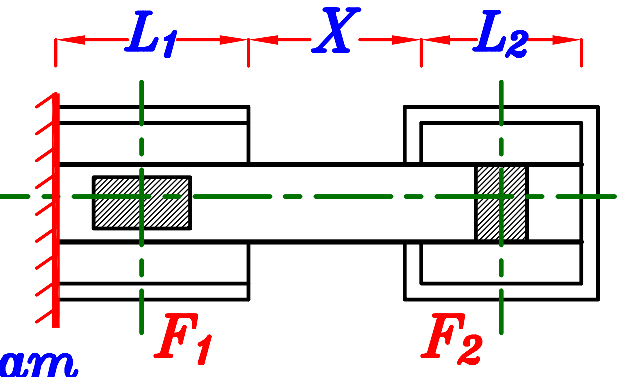
يتم التفكير فى استخدام Strap Beam

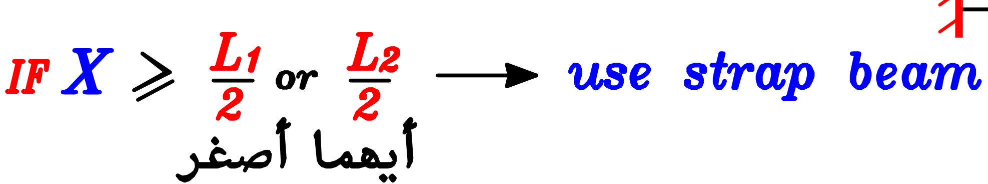
و لتحديد اذا كانت الـ Strap Beam تنفع أم لا
فيتم حساب أبعاد القواعد المنفصله F_1 , F_2



اذا حدث تداخل فى القواعد لن تنفع
الـ Strap Beam و نعمل Combined Footing

اذا كانت المسافه بين القواعد المسلحه X
أصغر من $\frac{L_1}{2}$ and $\frac{L_2}{2}$ لن تنفع Strap Beam
و نعمل Combined Footing

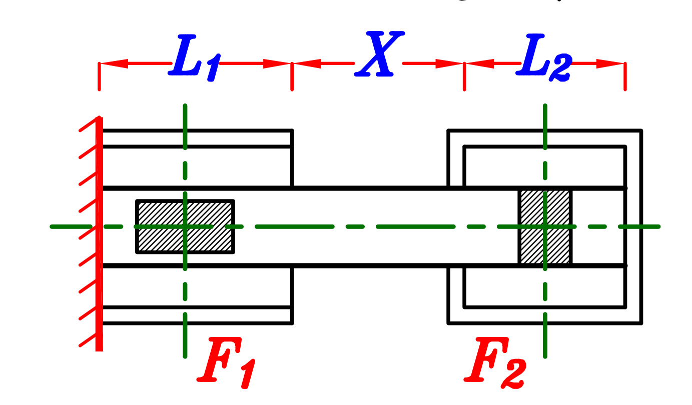


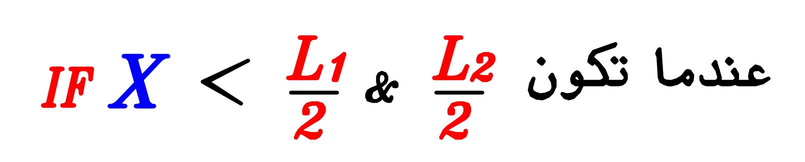


IF $X \geq \frac{L_1}{2}$ or $\frac{L_2}{2}$ ⟶ use strap beam
أيهما أصغر

2-Combined Footing. قاعده مشتركه

اذا لم ينفع حل ال **Strap Beam**

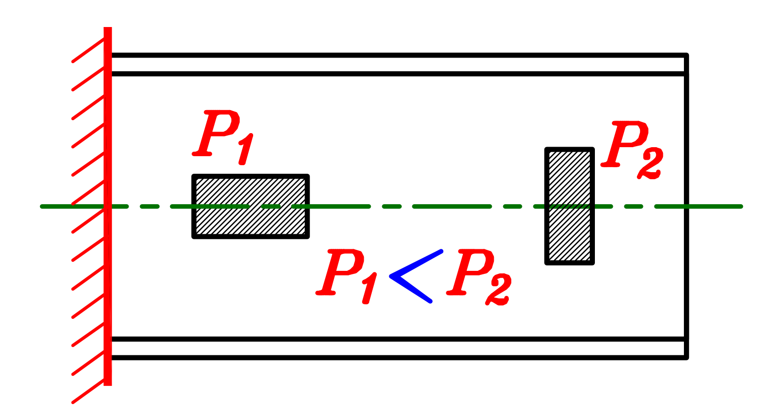




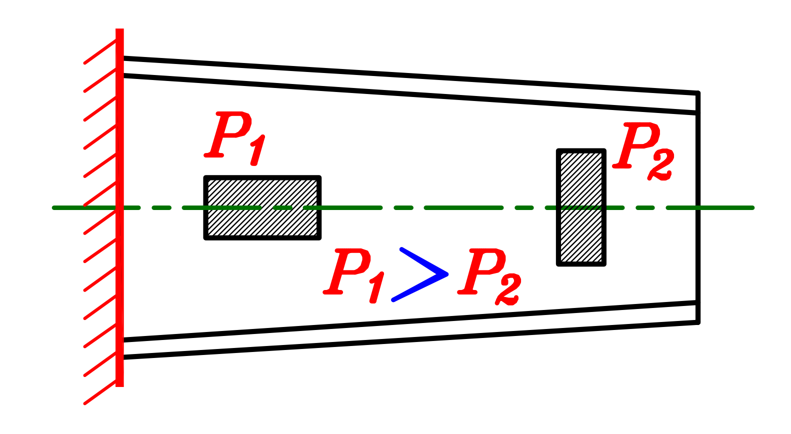
IF $X < \frac{L_1}{2}$ & $\frac{L_2}{2}$ عندما تكون

يتم عمل قاعده مشتركه و يكون شكلها كالاتى :

1- IF $P_1 < P_2$ use *Rectangular* combined Footing.

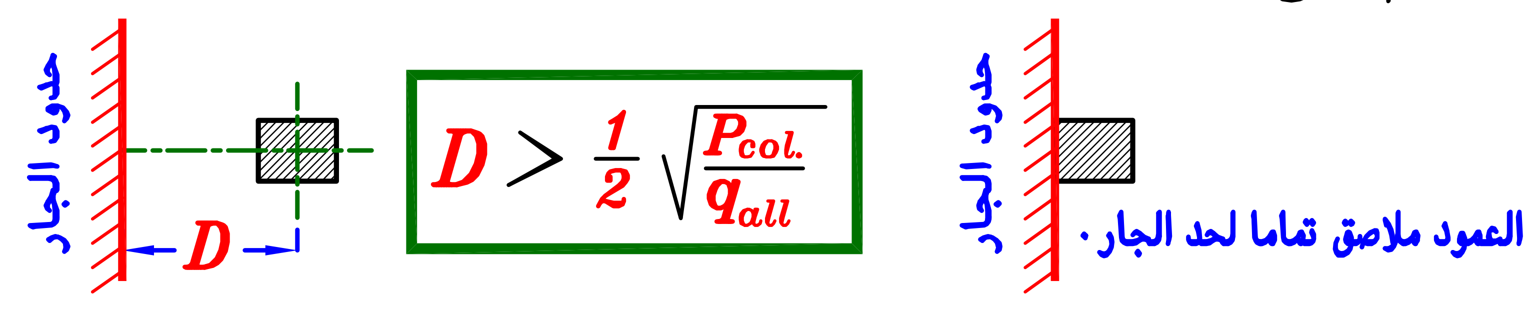


2- IF $P_1 > P_2$ use *Trapezoidal* combined Footing.



Design of Strap Beam.

اذا لم ينفع حل القواعد المنفصله للاسباب السابقه .



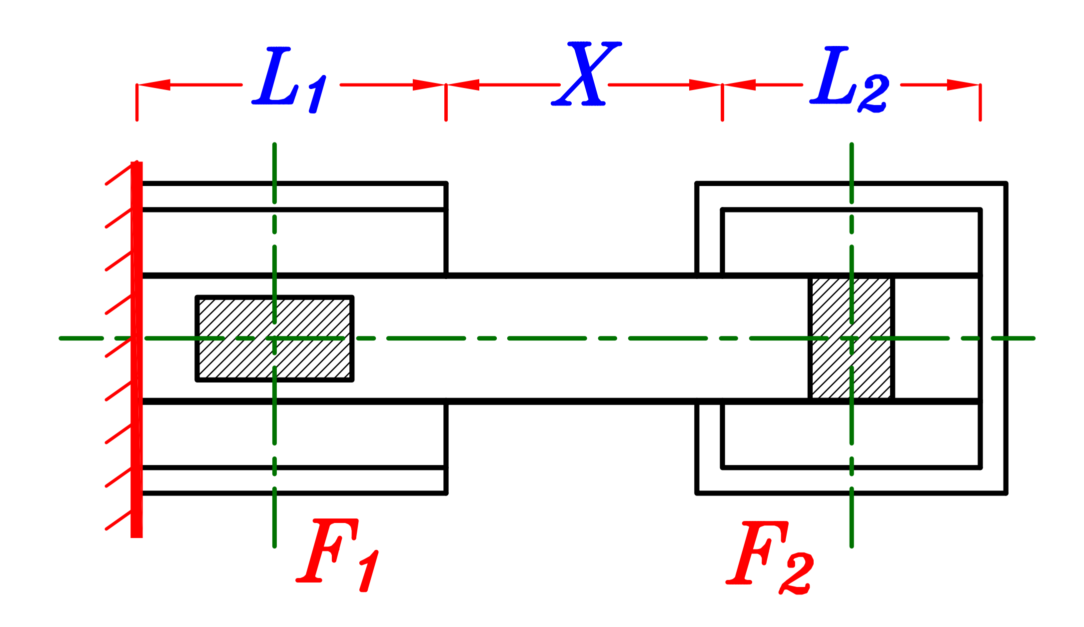
يتم التفكير أولا فى استخدام Strap Beam

و لتحديد اذا كانت الـ Strap Beam تنفع أم لا فيتم حساب أبعاد القواعد المنفصله F_1 , F_2

اذا حدث تداخل فى القواعد لن تنفع الـ Strap Beam و نعمل Combined Footing

اذا كانت المسافه بين القواعد المسلحه X أصغر من $\frac{L_1}{2}$ and $\frac{L_2}{2}$

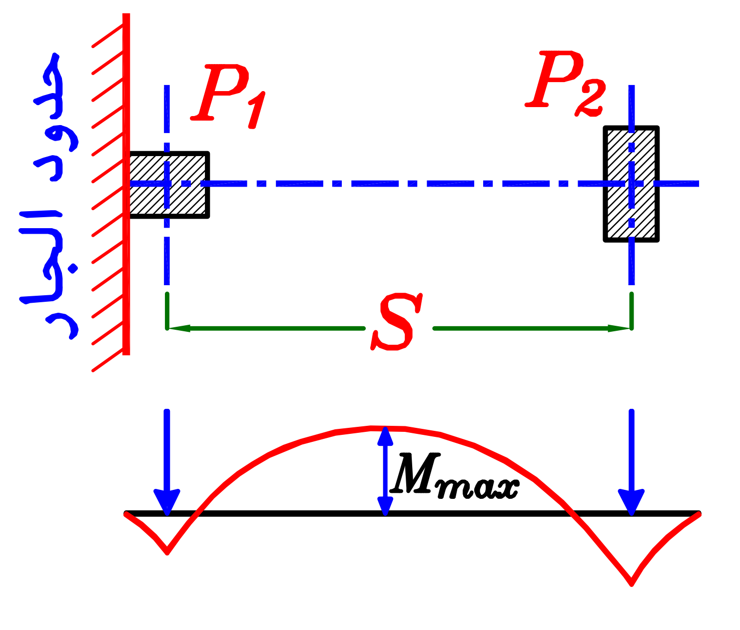
لن تنفع Strap Beam



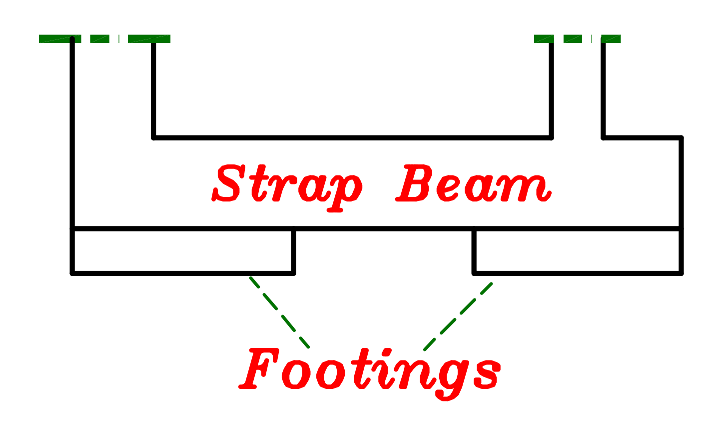
$$\text{IF } X \geqslant \frac{L_1}{2} \text{ or } \frac{L_2}{2} \longrightarrow \text{use strap beam}$$

أيهما أصغر

الفكره العامه لاختيار *Strap Beam*



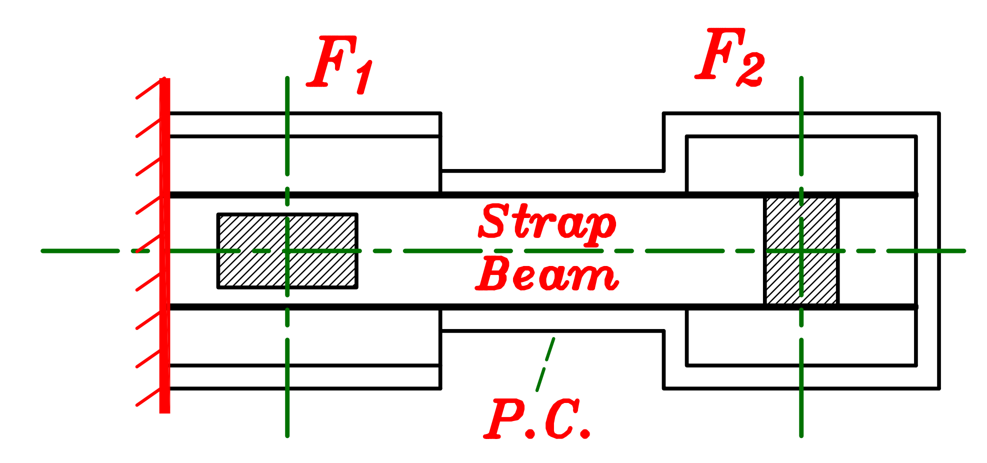
عندما تكون المسافه (S) بين العمود ناحيه الجار و العمود الداخلى كبيره و المفترض عمل قاعده مشتركه تربط بين العمودين معا فان طول هذه القاعده يكون كبير جدا و بالتالى يكون عليها عزم كبير جدا (M_{max}) .



لذلك نلجاء لفكره الـ *Strap Beam* و هى أن أحمال الاعمده تنزل أولا على كمره كبيره (ذات عرض و عمق كبيرين) ثم يتم عمل قاعدتين أسفل العمودين ليكونا بمثابه *supports* للكمره لنقل الـ *reactions* الى التربه .

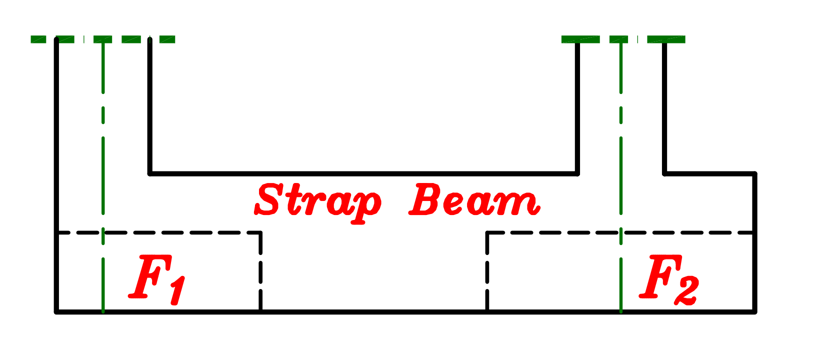
ترتيب نقل حمل العمود يكون كالاتى :

Columns → *Strap Beam* → 2 *Footings* → *Soil*



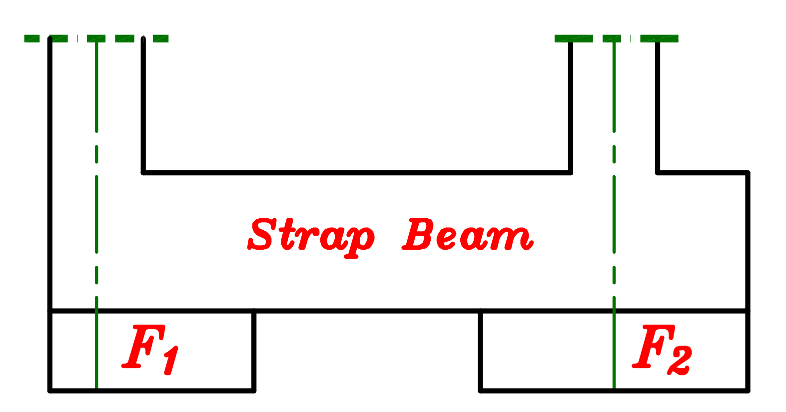
أشكال الـ Strap Beam و القاعدتين .

١- منسوب قاع القاعدتين
عند منسوب قاع الكمره



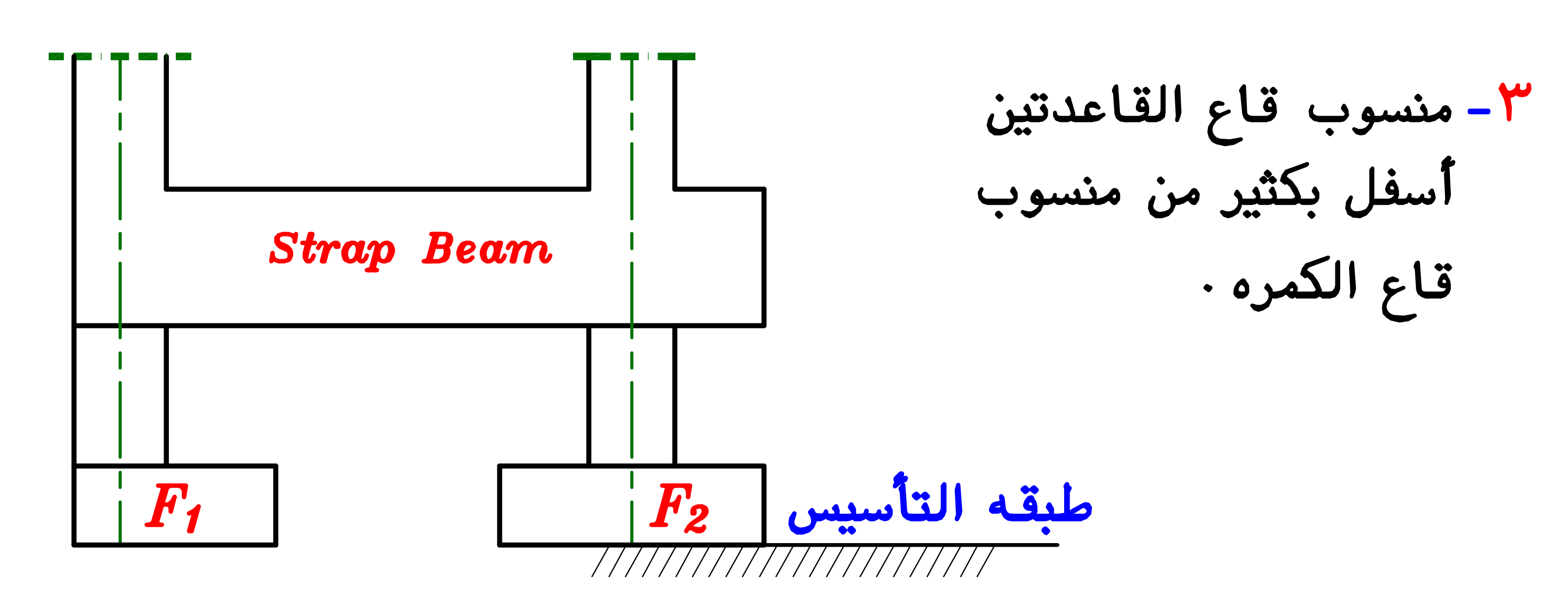
و هو الاكثر استخداما لانه أوفر فى عمق الحفر

٢- منسوب قاع القاعدتين
أسفل منسوب قاع الكمره



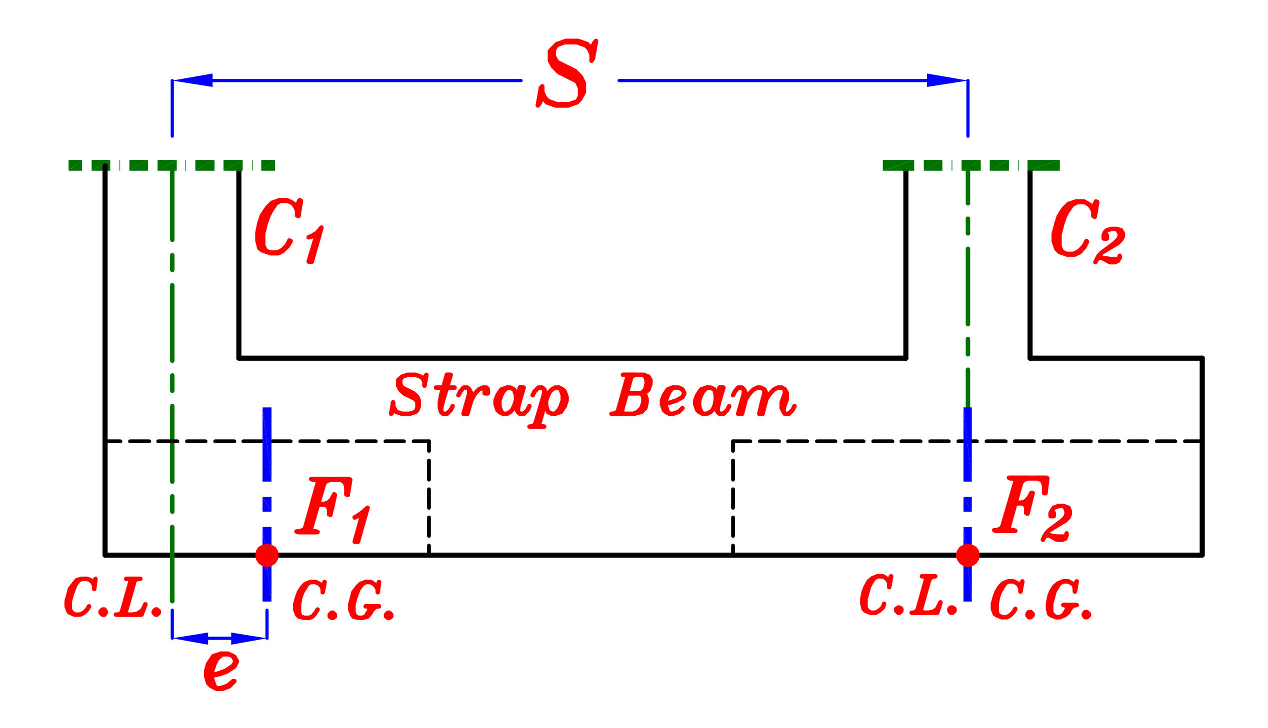
هذا الحل غير مفضل لانه يحتاج عمق حفر كبير .
و يتطلب معه أن يكون سمك القاعدتين واحد .

٣- منسوب قاع القاعدتين
أسفل بكثير من منسوب
قاع الكمره .



هذا الحل نلجأ له عندما تكون طبقه التأسيس عميقه .

Important Notes. ملحوظه هامه .



١- مركز القاعده أسفل العمود الداخلى يكون أسفل محور العمود مباشره .

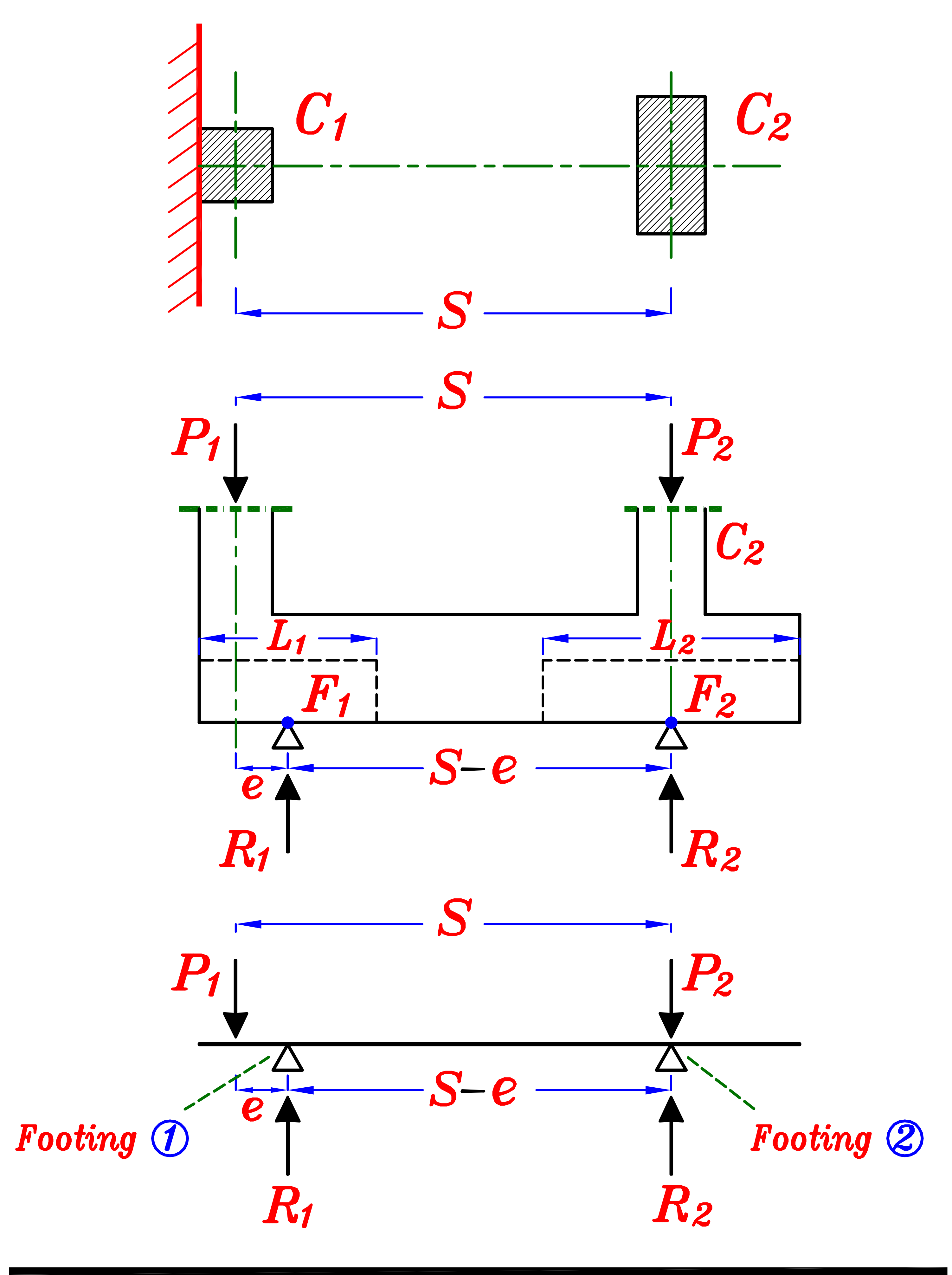
C.G. القاعده F_2 تكون منطبقة مع C.L. العمود C_2 .

٢- مركز القاعده F_1 أسفل عمود الجار C_1 يكون على بعد مسافه (e) من محور العمود .

$$e = 0.1 + 0.2\,(S)$$

و ذلك حتى لا تدخل القاعده F_1 فى منطقة الجار .

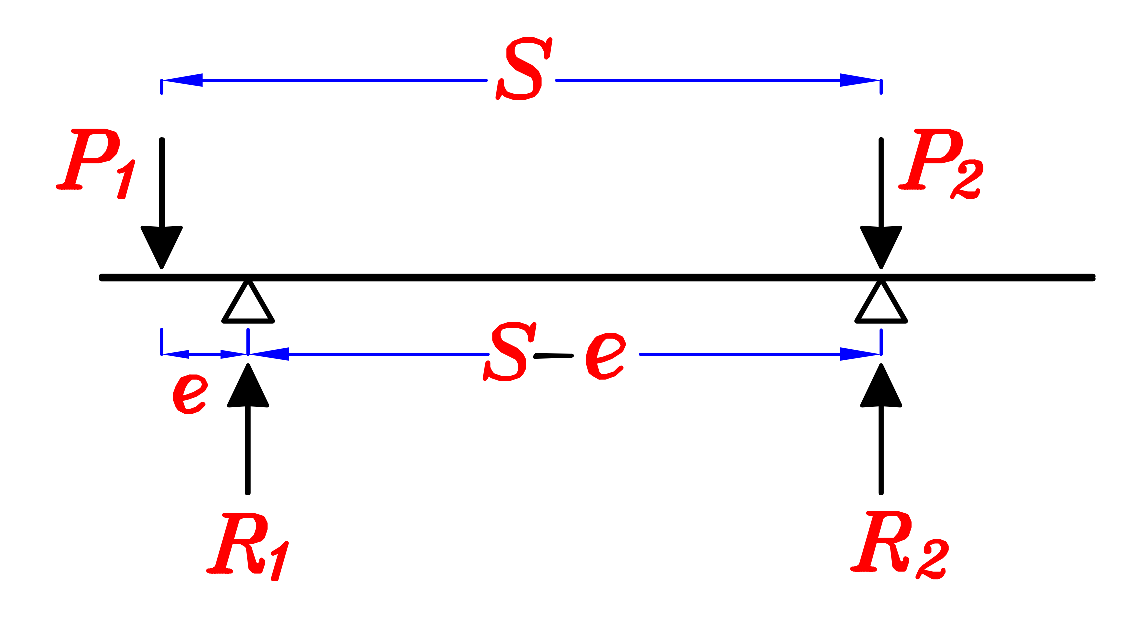
6 a Design the Strap Beam and the two Footings.



1 – Calculate the Footing area. (Width & Length of R.C. Footings.)

- Take $e = 0.1 + 0.2\ (S)$

- Calculate the reactions on Footings R_1 , R_2



$$P_1 * S = R_1 * (S - e)$$

$$R_1 = \frac{P_1 * S}{S - e}$$

$$P_1 + P_2 = R_1 + R_2 \longrightarrow R_2 = R_1 - P_1 - P_2$$

Footing F_1

IF $t_{P.C.} > 20\ cm$

$$L_{1\,P.C.} = 2\left(e + \frac{C_1}{2}\right)$$

get $B_{1\,P.C.}$ From

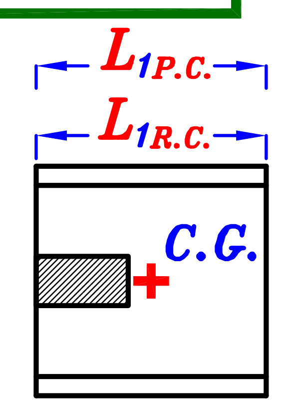
$$A_{P.C.} = \frac{R_1}{q_{all}} = \checkmark\checkmark\ m^2$$

$$A_{P.C.} = B_{1P.C.} * L_{1\,P.C.} \longrightarrow B_{1P.C.} = \checkmark$$

بعد حساب $B_{1\,P.C.}$ تقرب لاقرب ٥٠ مم بالزياده

$$B_{1R.C.} = B_{1P.C.} - 2\ t_{P.C.}$$

$$L_{1R.C.} = L_{1P.C.}$$

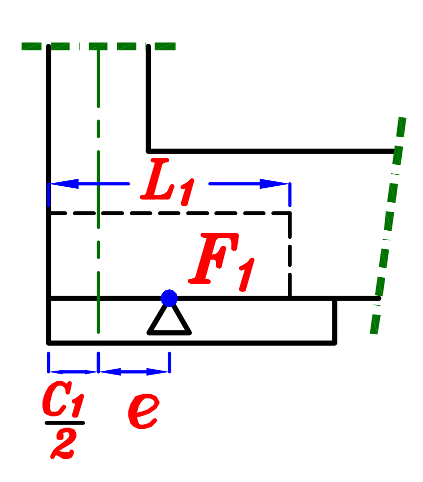


لا يوجد بروز للقاعده العاديه

حتى يكون C.G. للقاعده العاديه ينطبق على C.G. للقاعده المسلحه

IF $t_{P.C.} < 20\ cm$

$$L_{1\,R.C.} = 2\left(e + \frac{C_1}{2}\right)$$

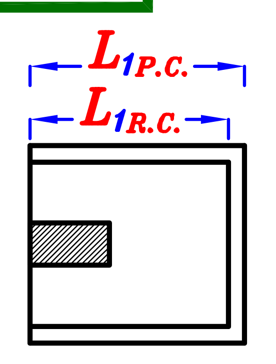


Get $B_{1\,R.C.}$ From $A_{R.C.} = \dfrac{R_1}{q_{all}} = \checkmark\checkmark\ m^2$

$$A_{R.C.} = B_{1R.C.} * L_{1\,R.C.} \longrightarrow B_{1\,R.C.} = \checkmark$$

$$B_{1P.C.} = B_{1R.C.} + 2\ t_{P.C.}$$

$$L_{1P.C.} = L_{1R.C.} + t_{P.C.}$$

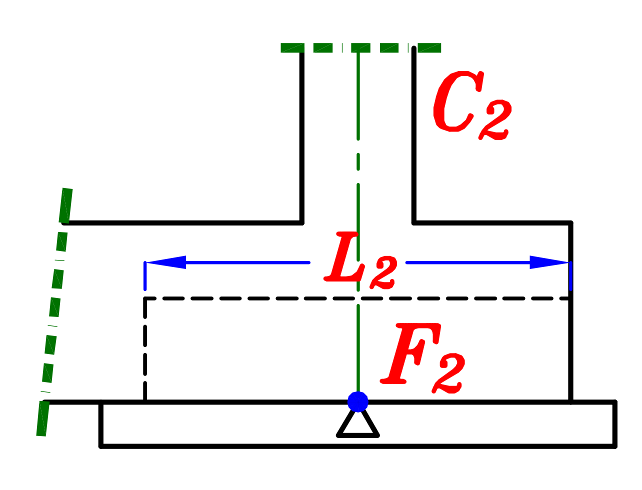


بروز من ناحيه واحده لان الناحيه الاخرى عندها حد الجار

لا يهم فى هذه الحاله أن ينطبق C.G. للقاعده العاديه و المسلحه

لان القاعده العاديه فى هذه الحاله فرشه نظافه .

Footing F_2



IF $t_{P.C.} > 20\ cm$

get $B_{P.C.}$, $L_{P.C.}$ From

$$A_{P.C.} = \frac{R_2}{q_{all}} = \checkmark\checkmark\ m^2 = B_{2\,P.C.} * L_{2\,P.C.} \text{ ------ } (1)$$

$$L_{2\,P.C.} - B_{2\,P.C.} = b - a \text{ ------ } (2)$$

بعد حساب $B_{2\,P.C.}$ & $L_{2\,P.C.}$ يقربا لاقرب ٥٠ مم بالزياده

$$B_{2\,R.C.} = B_{2\,P.C.} - 2\ t_{P.C.}$$

$$L_{2\,R.C.} = L_{2\,P.C.} - 2\ t_{P.C.}$$

IF $t_{P.C.} < 20\ cm$

get $B_{R.C.}$, $L_{R.C.}$ From

$$A_{R.C.} = \frac{R_2}{q_{all}} = \checkmark\checkmark\ m^2 = B_{2\,R.C.} * L_{2\,R.C.} \text{ ------ } (1)$$

$$L_{2\,R.C.} - B_{2\,R.C.} = b - a \text{ ------ } (2)$$

بعد حساب $B_{2\,R.C.}$ & $L_{2\,R.C.}$ يقربا لاقرب ٥٠ مم بالزياده

$$B_{2\,P.C.} = B_{2\,R.C.} + 2\ t_{P.C.}$$

$$L_{2\,P.C.} = L_{2\,R.C.} + 2\ t_{P.C.}$$

2- Check the validity of using Strap Beam.

نتأكد من سماحيه عمل Strap Beam أم لا .

نرسم sketch للقاعدتين F_2 , F_1 و نحدد عليه أبعاد كل قاعده .

IF $t_{P.C.} > 20$ cm

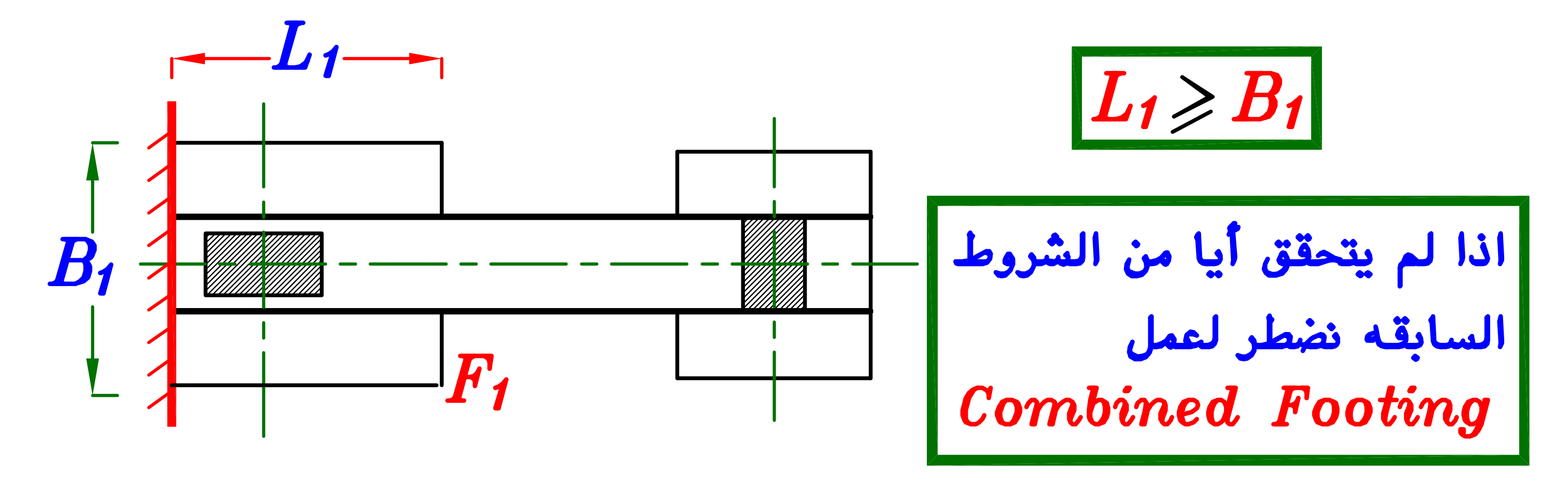
IF $t_{P.C.} < 20$ cm

شروط استخدام الـ Strap Beam .

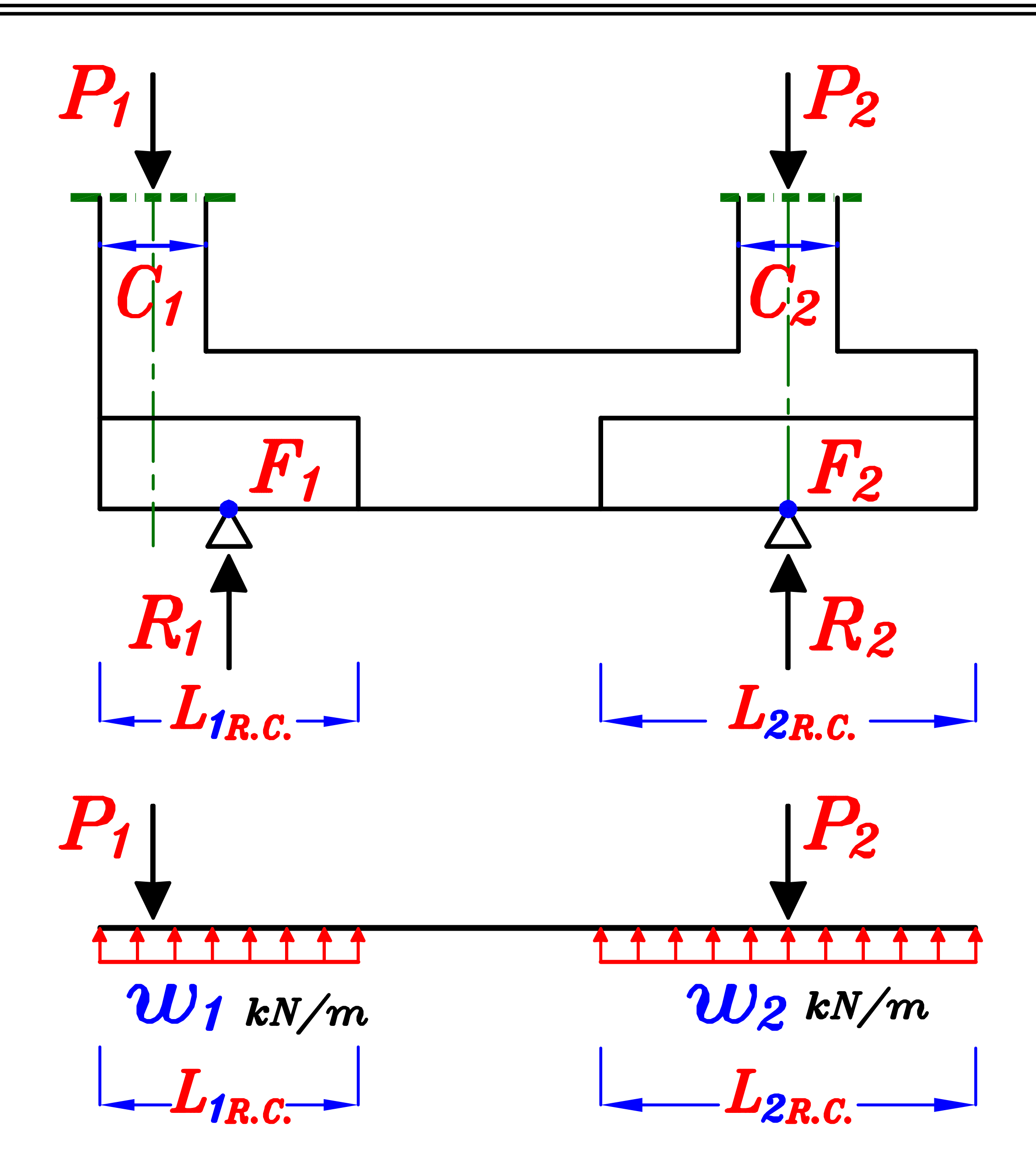
١- عدم حدوث تداخل بين القاعدتين F_1 , F_2

٢- أن لا تقل المسافه X عن الاصغر من $\frac{L_2}{2}$ and $\frac{L_1}{2}$

٣- يفضل أن تكون أبعاد القاعده F_1 لها الاستطاله الاكبر فى اتجاه العمودى على حد الجار .



3 – Dimensions of the Strap Beam. (Width & Depth)

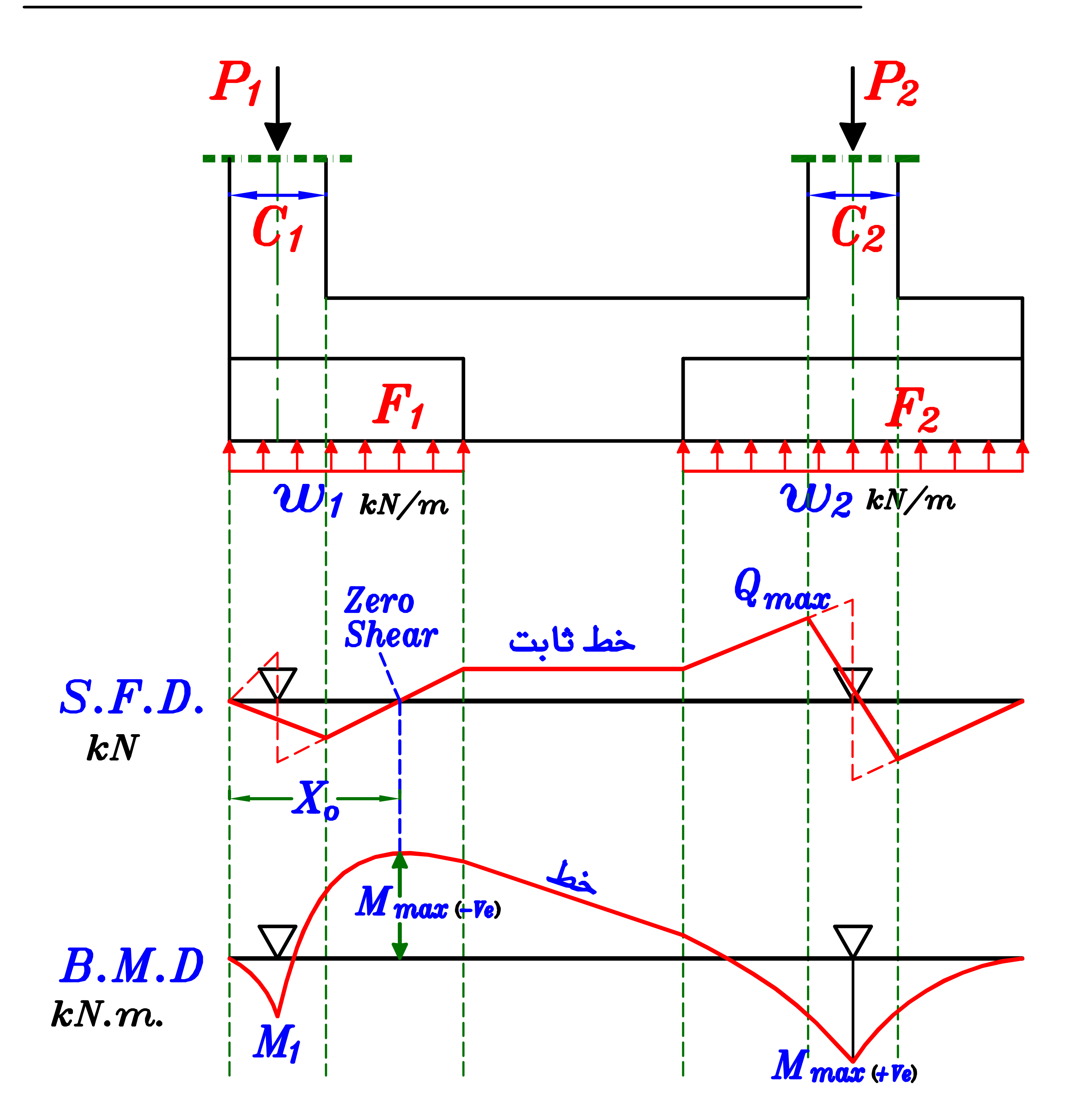


Stresses on Footings.

$$w_1 = \frac{R_1\ (U.L.)}{L_{1R.C.}} \quad (kN/m)$$

$$w_2 = \frac{R_2\ (U.L.)}{L_{2R.C.}} \quad (kN/m)$$

Drawing B.M.D. & S.F.D. For the Beam.



To Calculate the point of Zero Shear.

$$w_1 = P_1 (X_o) \longrightarrow X_o = \checkmark$$

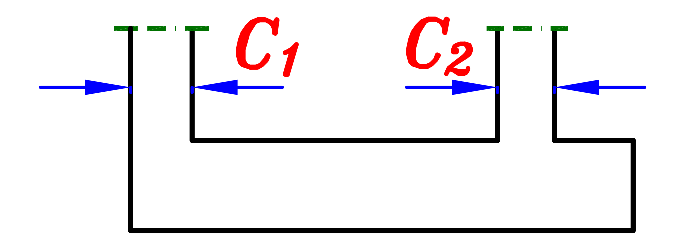
To Calculate the max (-Ve) Moment.

$$M_{max\,(-Ve)} = P_1 \left(X_o - \frac{C_1}{2}\right) - w_1 \frac{(X_o)^2}{2}$$

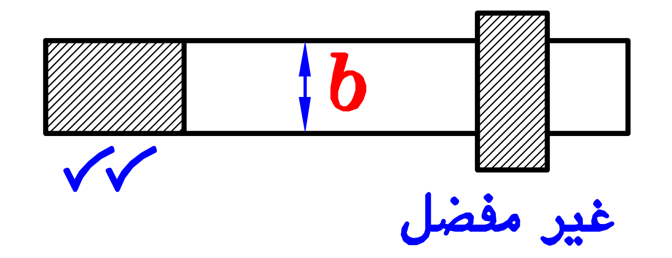
M_{max} the bigger From M_{max} (−Ve) & M_{max} (+Ve)

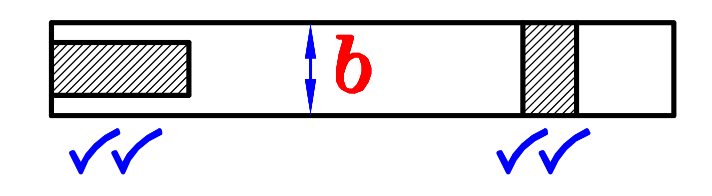
Choose $b = (400 \rightarrow 1000)$ mm

$b \nless C_1$ or C_2



لا يقل عرض الكمره عن عرض العمود العمودى عليها





$$\text{Recommended } b \simeq \frac{d}{2}$$

$$d_{(mm)} = C_1 \sqrt{\frac{M_{max}\ (kN.m) * 10^6}{F_{cu}\ (N/mm^2) * b\ (mm)}}$$

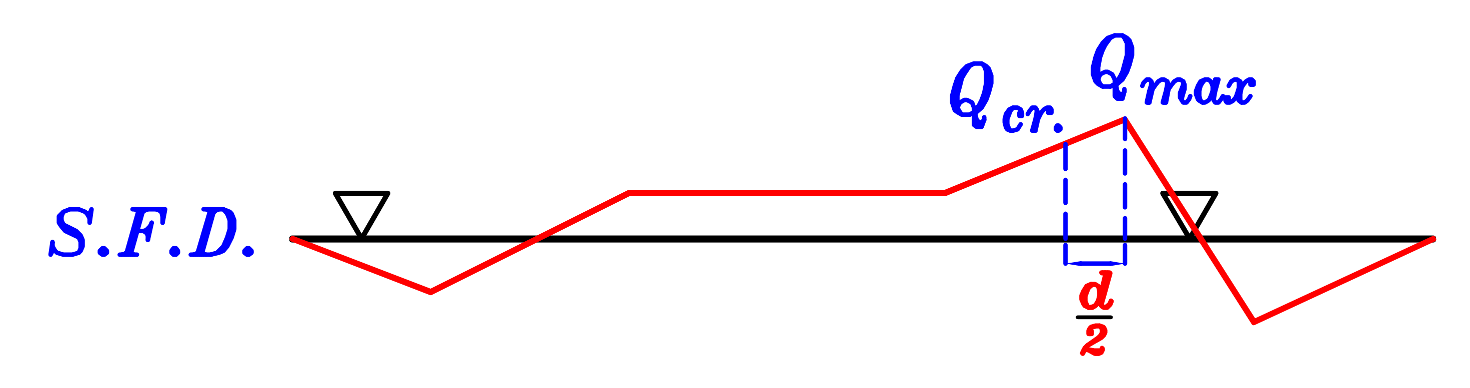
Choose $C_1 = (3.5 \rightarrow 5.0)$

Get d = ✓✓ (mm)

Take cover = 70 mm

$t = d + \text{cover}\ (70\ mm)$ تقرب لاقرب ٥٠ مم بالزياده

4 – Check Shear For Strap Beam. as beams.



$$Q_{cr.} = Q_{max.} - w\left(\frac{d}{2}\right)$$

$Q_{cr.}$ على بعد $\frac{d}{2}$ من وش العمود

① **Calculate Allowable Shear Stresses.**

$$q_{cu} = 0.24 \sqrt{\frac{F_{cu}}{\gamma_c}} \quad N\backslash mm^2$$

$$q_{max.} = 0.70 \sqrt{\frac{F_{cu}}{\gamma_c}} \quad N\backslash mm^2$$

② **Calculate Actual Shear Stress.**

$$q_U = \frac{Q_{cr.}}{b\,d} \quad N\backslash mm^2$$

③ **IF** q_U

- $q_U \leqslant q_{cu}$ — Use min. Stirrups. $5\phi 10\backslash m'$, 4 branches
- $q_{cu} < q_U \leqslant q_{Umax.}$ — We need Stirrups More Than $5\phi 10\backslash m'$
- $q_U > q_{Umax.}$ — Increase Dim. b or d

* IF $q_{cu} < q_U < q_{U\,max.}$

We need Stirrups more than $5\phi 8 \backslash m'$

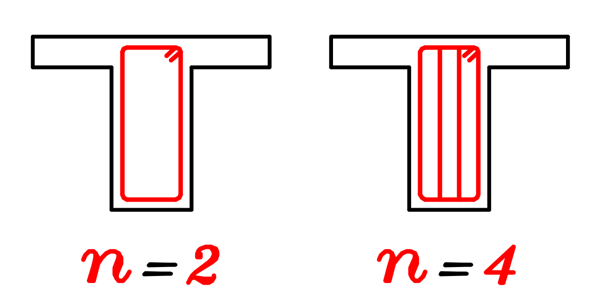
$$q_{su} = q_u - \frac{q_{cu}}{2} = \frac{n\, A_s\, (F_y \backslash \gamma_s)}{b\; S}$$

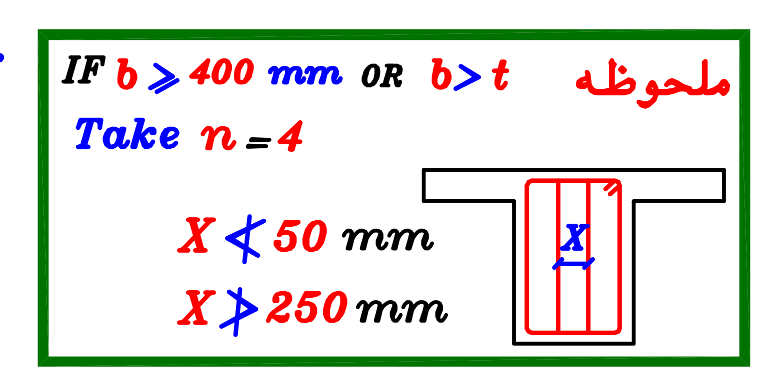
Where : q_{su} = Shear Stress Taken by Stirrups only.

q_u = Actual Shear Stress.

$\frac{q_{cu}}{2}$ = Shear Stress Taken by Concrete only.

- n = No. of Branches.

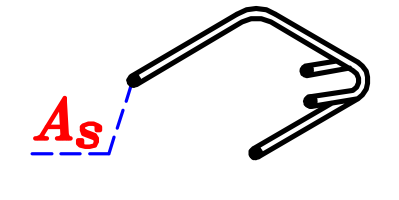




- A_s مساحه سطح السيخ الواحد من الكانه

IF using $\phi 8 \longrightarrow A_s = 50.3\ mm^2$

IF using $\phi 10 \longrightarrow A_s = 78.5\ mm^2$



- $F_y = 240\ N\backslash mm^2$ Mild Steel

$F_y = 360\ N\backslash mm^2$ H.T.Steel

- S = Spacing between stirrups in the Long Direction.

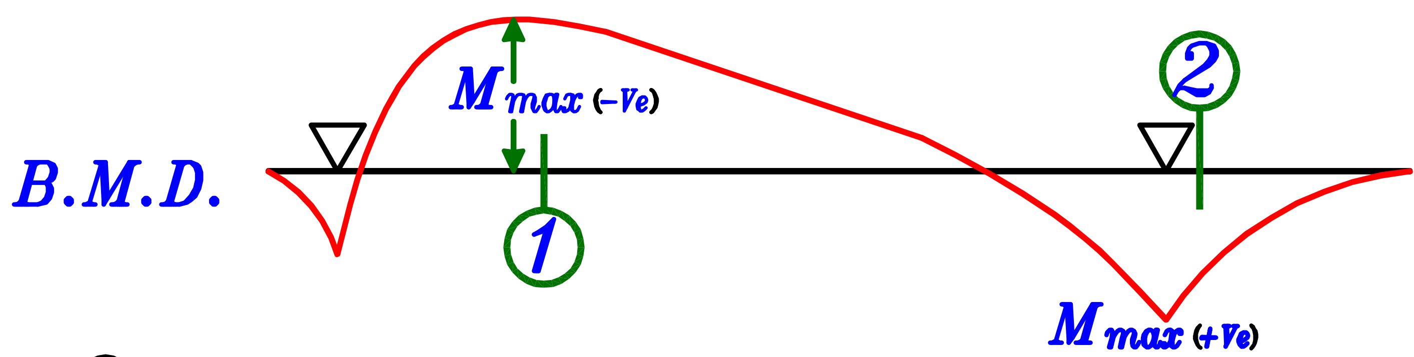
المسافات بين الكانات فى الإتجاه الطولى

$S_{min} = 100\ mm$

$S_{max.} = 200\ mm$

S

5 – Reinforcement of Strap Beam.



Sec. ①

$$d = C_1 \sqrt{\frac{M_{max\,(-Ve)}}{F_{cu} * b}} \longrightarrow C_1 \longrightarrow J$$

Get
$$A_{s\,Top} = \frac{M_{max\,(-Ve)}}{J\,F_y\,d} \quad (mm^2)$$

Check
$$A_{s\,min} = \text{الأكبر}\begin{cases} \text{الأقل}\begin{cases} 0.225 * \frac{\sqrt{F_{cu}}}{F_y}\, b\,d \\ 1.3\,A_{s\,req.} \end{cases} \\ \frac{0.15}{100}\, b\,d \end{cases}$$

Sec. ②

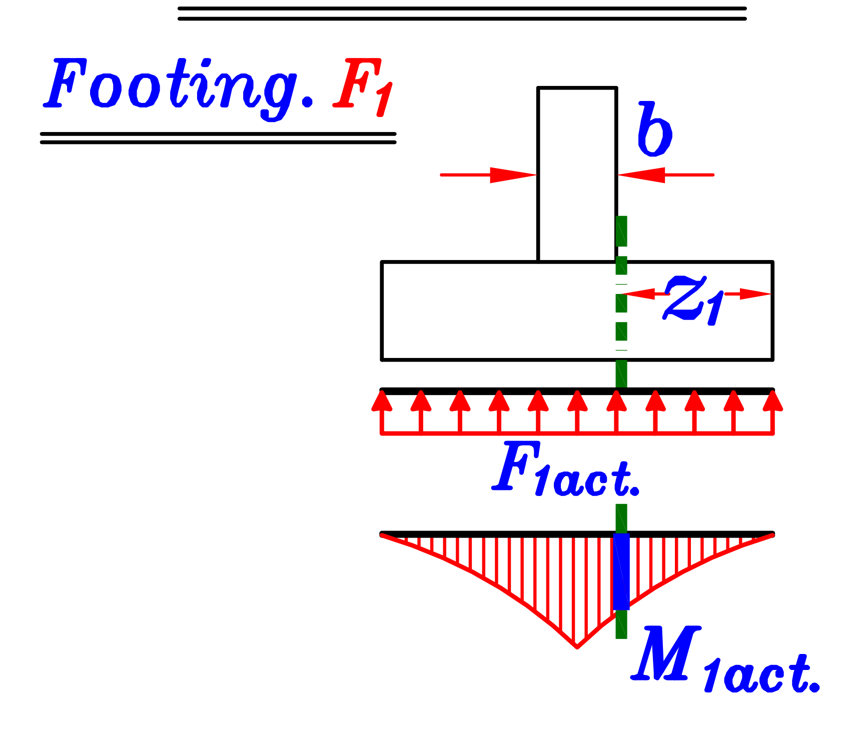
$$d = C_1 \sqrt{\frac{M_{max\,(+Ve)}}{F_{cu} * b}} \longrightarrow C_1 \longrightarrow J$$

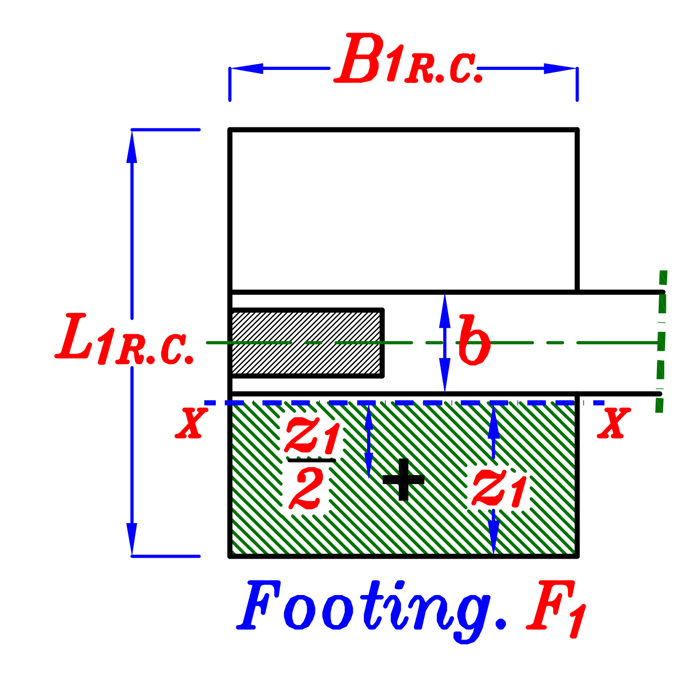
Get
$$A_{s\,bott} = \frac{M_{max\,(+Ve)}}{J\,F_y\,d} \quad (mm^2)$$

Check $A_{s\,min}$

6 – Design of Footings. as a strip Footing.

Footing. F_1





– Actual Normal stress on R.C. Footing (U.L.)

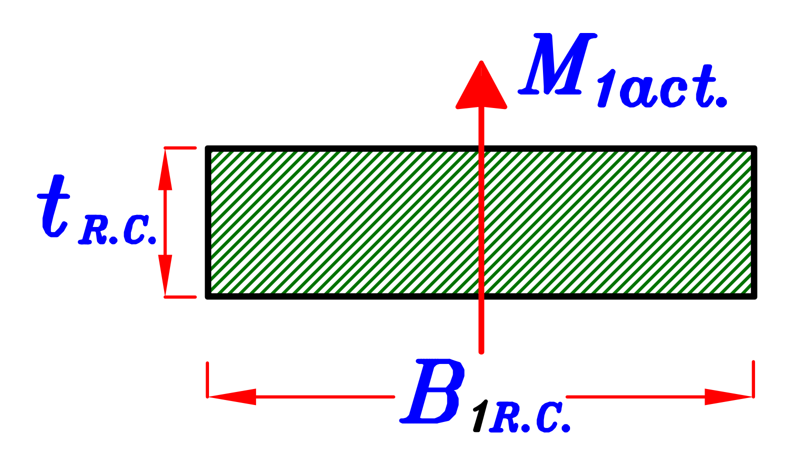
$$F_{1act.} = \frac{R_{1U.L.}}{B_{1R.C.} * L_{1R.C.}} \quad (kN/m^2)$$

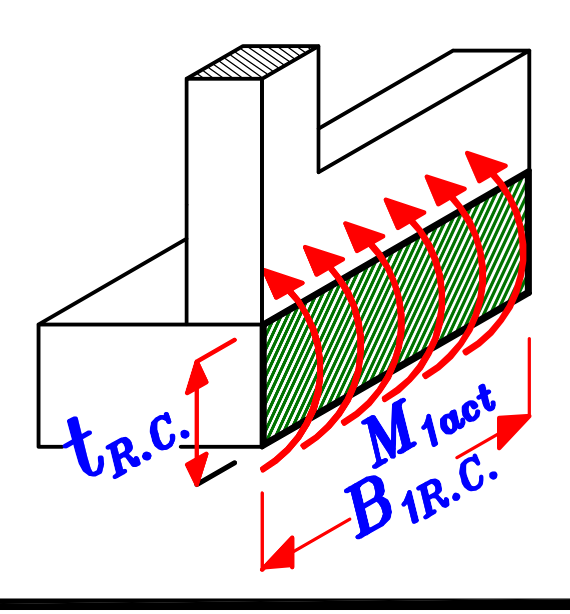
– Critical section of bending at R.C. Footing.

$$Z_1 = \frac{L_{1R.C.} - b}{2} \quad (m)$$

– moment = Force * Distance

$$M_{1act.} = (F_{1act.} * Z_1 * B_{1R.C.}) \frac{Z_1}{2} \quad (kN.m.)$$





$$d_1 = C_1 \sqrt{\frac{M_{1act.}}{F_{cu} * B_{1R.C.}}}$$

Take $C_1 = (3.5 \rightarrow 5.0)$

Get $d_1 = ✓✓$ (mm)

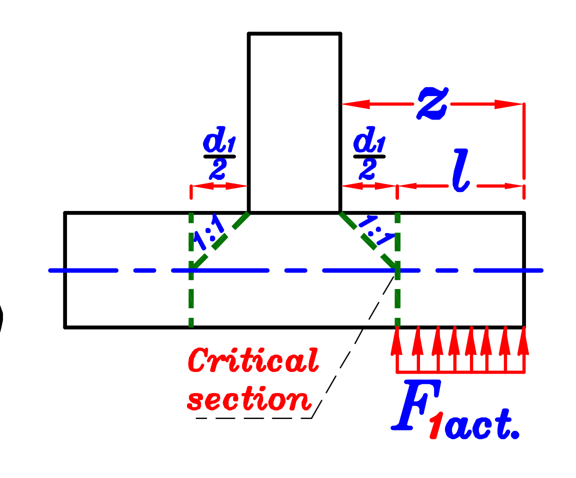
Take cover = 70 mm

$$t_{1\,R.C.} = d_1 + cover\ (70\ mm)$$

تقرب لاقرب ٥٠ مم بالزياده

Check Shear.

* Calculate $l_1 = z_1 - \frac{d_1}{2}$ (m)

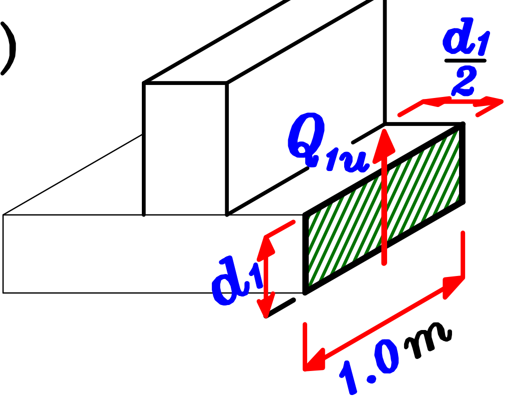


* Calculate Actual shear Force. (Q_u)

$$Q_{1u} = F_{act.} * l_1 * 1.0\,m \quad (kN)$$

* Calculate Actual shear stress. (q_u)

$$q_{u1} = \frac{Q_{1u}}{b * d_1} = \frac{Q_{1u}\,(kN) * 10^3}{1000 * d_1\,(mm)}$$



* Calculate Allowable shear stress. (q_{su})

$$q_{su} = 0.16 \sqrt{\frac{F_{cu}}{\gamma_c}}$$

* Compare between

Actual shear stress (q_u) & Allowable shear stress (q_{su})

* IF $q_{u1} \leqslant q_{su} \longrightarrow$ Safe shear stresses
No need to increase dimensions.

* IF $q_{u1} > q_{su} \longrightarrow$ UnSafe shear stresses
We have to increase dimensions.

Reinforcement of the Footing.

From $C_1 \xrightarrow{Get} J$

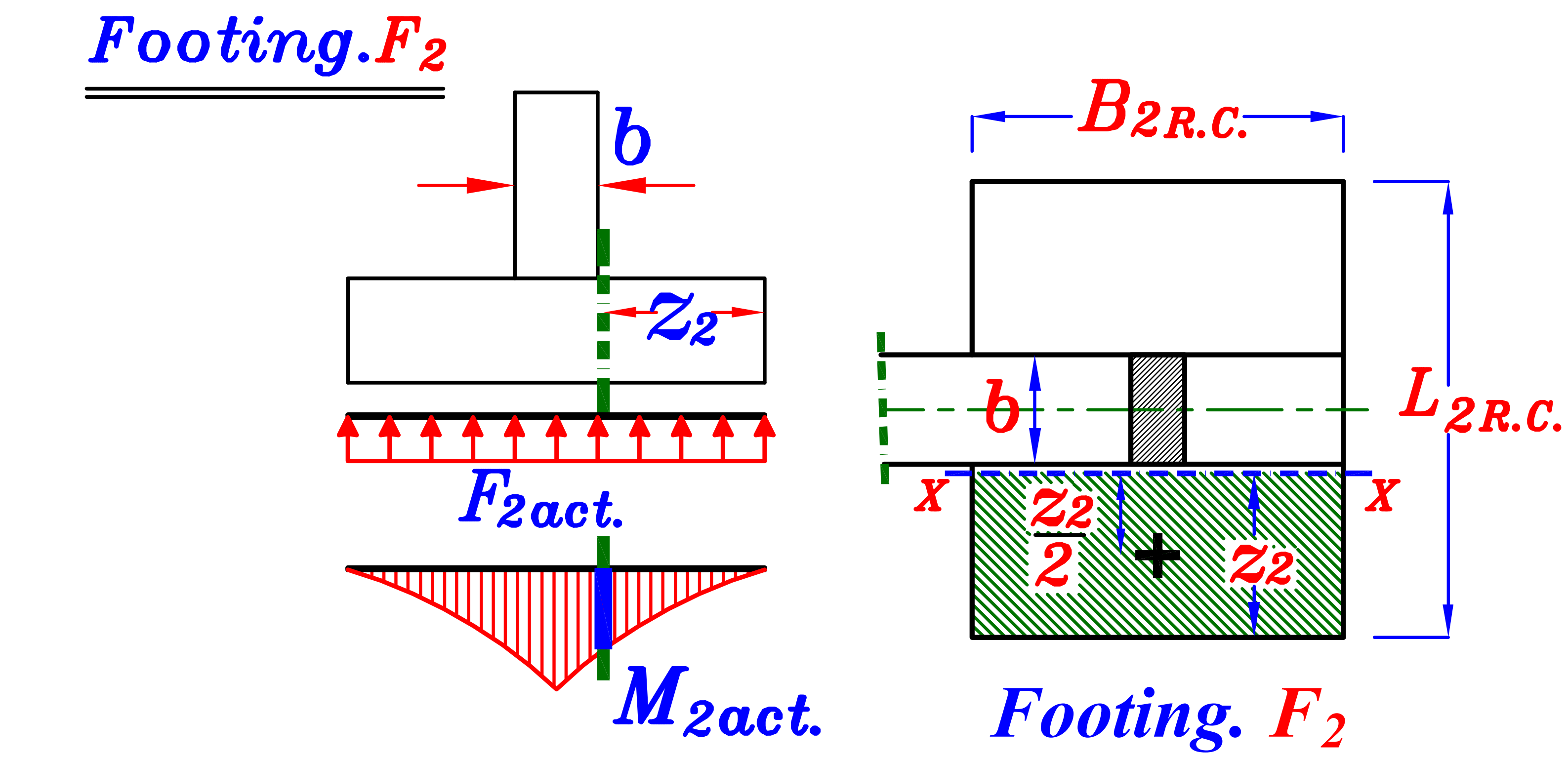
Get $$A_{s1} = \frac{M_{1act.}}{J \, F_y \, d_1} \quad (mm^2)$$

Check $$A_{s_{min}} \; (mm^2/m) = \begin{cases} 1.5\, d \; (mm) \\ 5 \phi 12 / m' \end{cases} \text{الأكبر}$$

IF $A_{s1} \geqslant A_{s_{min}} \longrightarrow$ o.k.

IF $A_{s1} < A_{s_{min}} \longrightarrow$ Take $A_{s1} = A_{s_{min}}$

Footing. F_2



- Actual Normal stress on R.C. Footing (U.L.)

$$F_{2act.} = \frac{R_{2U.L.}}{B_{2R.C.} * L_{2R.C.}} \quad (kN/m^2)$$

- Critical section of bending at R.C. Footing.

$$Z_2 = \frac{L_{2R.C.} - b}{2} \quad (m)$$

- moment = Force * Distance

$$M_{2act.} = (F_{2act.} * Z_2 * B_{2R.C.}) \frac{Z_2}{2} \quad (kN.m)$$

$M_{2act.}$

$t_{R.C.}$

$B_{2R.C.}$

$t_{R.C.}$

M_{2act}

$B_{2R.C.}$

$$d_2 = C_1 \sqrt{\frac{M_{2act.}}{F_{cu} * B_{1R.C.}}}$$

Take $C_1 = (3.5 \rightarrow 5.0)$

Get $d_2 = ✓✓$ (mm)

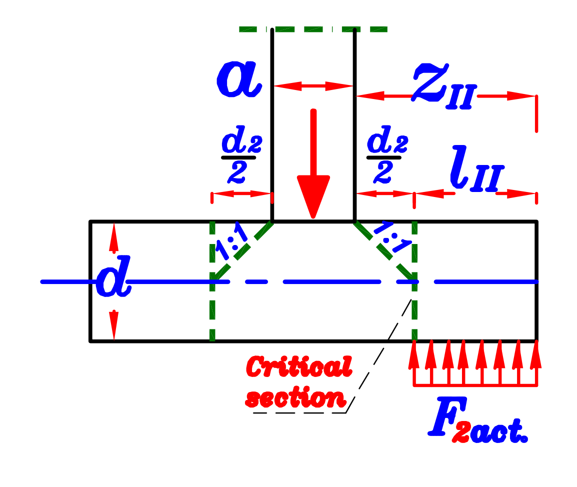
Take cover = 70 mm

$$t_{2\,R.C.} = d_2 + cover\ (70\ mm)$$

تقرب لاقرب ٥٠ مم بالزياده

Check Shear.

* Calculate $l_2 = z_2 - \frac{d_2}{2}$ (m)

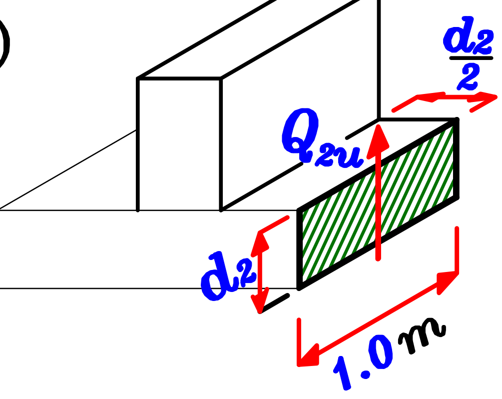


* Calculate Actual shear Force. (Q_u)

$$Q_{2u} = F_{act.} * l_2 * 1.0m \quad (kN)$$

* Calculate Actual shear stress. (q_u)

$$q_{2u} = \frac{Q_{2u}}{b * d_2} = \frac{Q_{2u}\,(kN) * 10^3}{1000 * d_2\,(mm)}$$



* Calculate Allowable shear stress. (q_{su})

$$q_{su} = 0.16 \sqrt{\frac{F_{cu}}{\delta_c}}$$

* Compare between

Actual shear stress (q_u) & Allowable shear stress (q_{su})

* IF $q_{u2} \leq q_{su}$ ⟶ Safe shear stresses
  No need to increase dimensions.

* IF $q_{u2} > q_{su}$ ⟶ UnSafe shear stresses
  We have to increase dimensions.

Reinforcement of the Footing.

From $C_1 \xrightarrow{Get} J$

Get

$$A_{s2} = \frac{M_{2act.}}{J \, F_y \, d_2} \quad (mm^2)$$

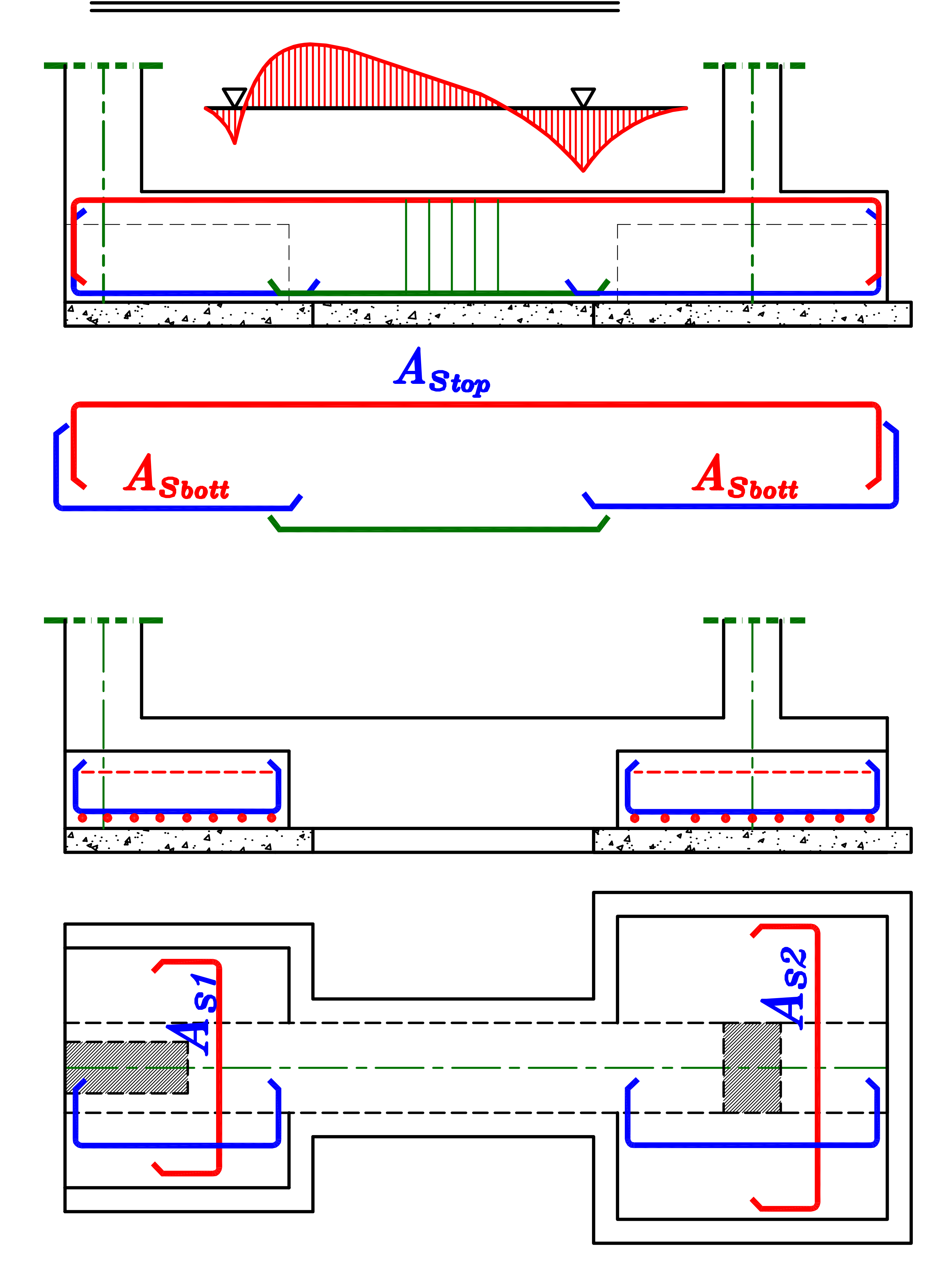
Check

$$A_{s\,min} \; (mm^2/m) = \begin{cases} 1.5\, d \; (mm) \\ 5 \phi 12 / m' \end{cases} \text{الأكبر}$$

IF $A_{s2} \geq A_{s\,min} \longrightarrow$ o.k.

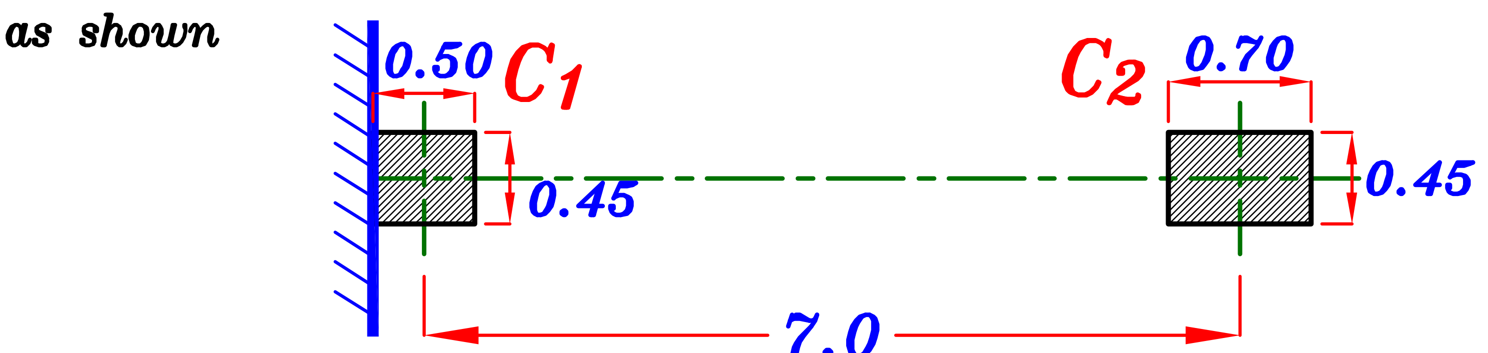
IF $A_{s2} < A_{s\,min} \longrightarrow$ Take $A_{s1} = A_{s\,min}$

7- Details of Reinforcement.



Example.

It is required to design Footings to support a proterty line column C_1 (45 * 50) cm. and carrying working load 1000 kN and interior column C_2 (45 * 70) cm. and carrying working load 2200 kN the spacing between the C.L. of the two columns is 7.0 m as shown



and the allowable net bearing capacity in the Footing site is 200 kN/m^2. (F_{cu} = 25 N/mm^2, F_y = 360 N/mm^2).
and draw details of RFT. to scale 1:50

Solution.

Data given.

Column C_1 dimensions (450 * 500) mm

P_1 (working) = 1000 kN P_1 (U.L.) = 1000 * 1.5 = 1500 kN

Column C_2 dimensions (450 * 700) mm

P_2 (working) = 2200 kN P_2 (U.L.) = 2200 * 1.5 = 3300 kN

$R_{(working)} = P_1 + P_2 = 3200$ kN

$R_{(U.L.)} = 1.5 * 3200 = 4800$ kN

Bearing capacity of the soil = $q_{all} = 200$ kN/m^2

$F_{cu} = 25$ N/mm^2 $F_y = 360$ N/mm^2

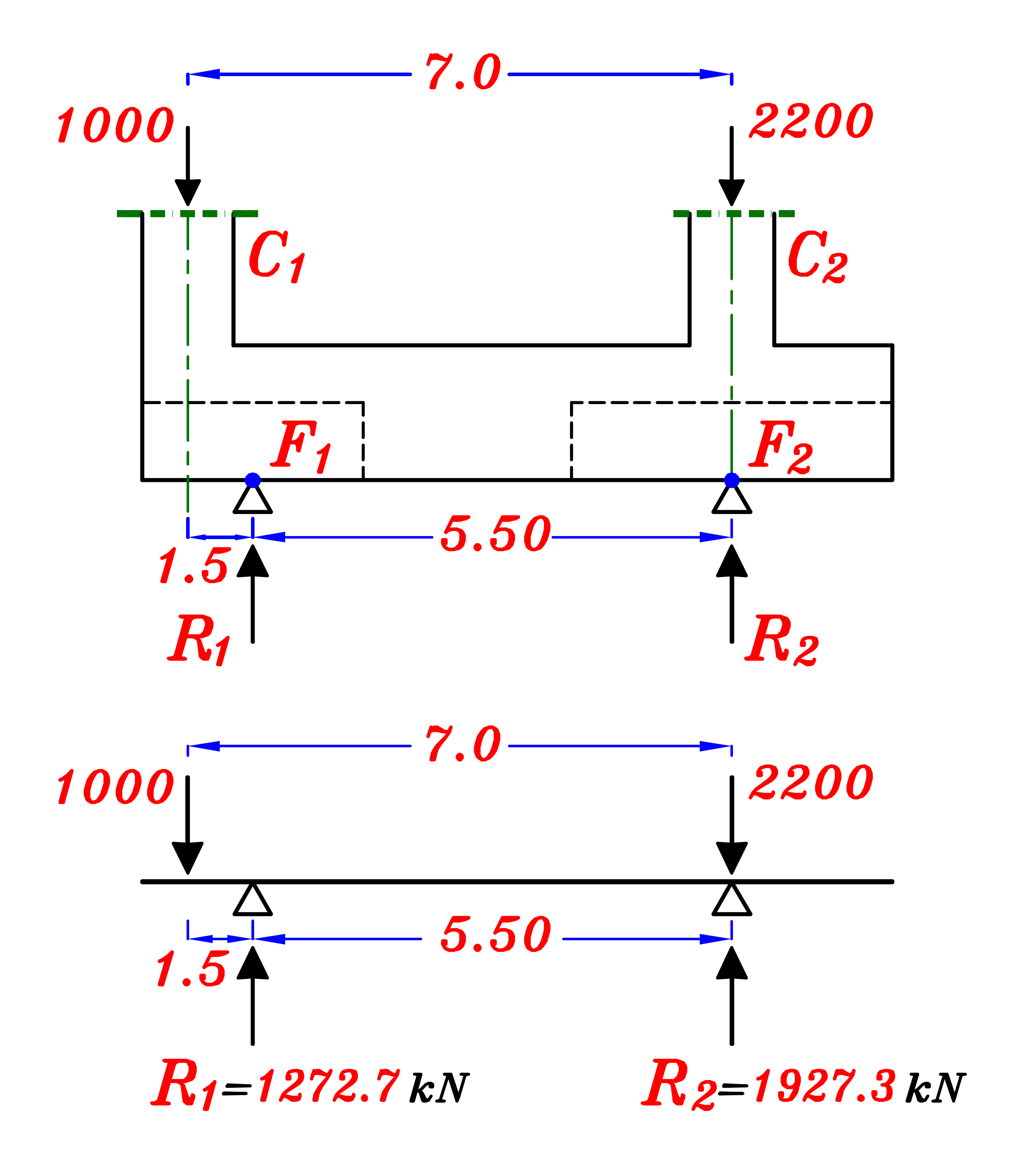
For property line use

Strap Beam or Combined Footing.

Start with Strap Beam.

1 – Calculate the Footing area. (Width & Length of R.C. Footings.)

Take $e = 0.1 + 0.2\,(S) = 0.1 + 0.2\,(7.0) = 1.50$ m



Footing F_1

Choose $t_{P.C.} = 30\ cm > 20\ cm$

$$L_{1\,P.C.} = 2\left(e + \frac{C_1}{2}\right) = 2\,(1.5 + 0.25) = 3.50\ m$$

0.5, L_1, F_1, 0.25, 1.5

get $B_{1\,P.C.}$ From $A_{P.C.} = \frac{R_1}{q_{all}} = A_{P.C.} = B_{1\,P.C.} * L_{1\,P.C.}$

$$A_{P.C.} = \frac{1272.7}{200} = B_{1\,P.C.} * 3.50 \longrightarrow B_{1\,P.C.} = 1.82\ m$$

$B_{1\,P.C.} = 1.90\ m$ $\quad$ $L_{1\,P.C.} = 3.50\ m$

$B_{1\,R.C.} = 1.30\ m$ $\quad$ $L_{1\,R.C.} = 3.50\ m$

Footing F_2

$$L_{2\,P.C.} - B_{2\,P.C.} = b - a = 0.70 - 0.45 = 0.25\ m$$

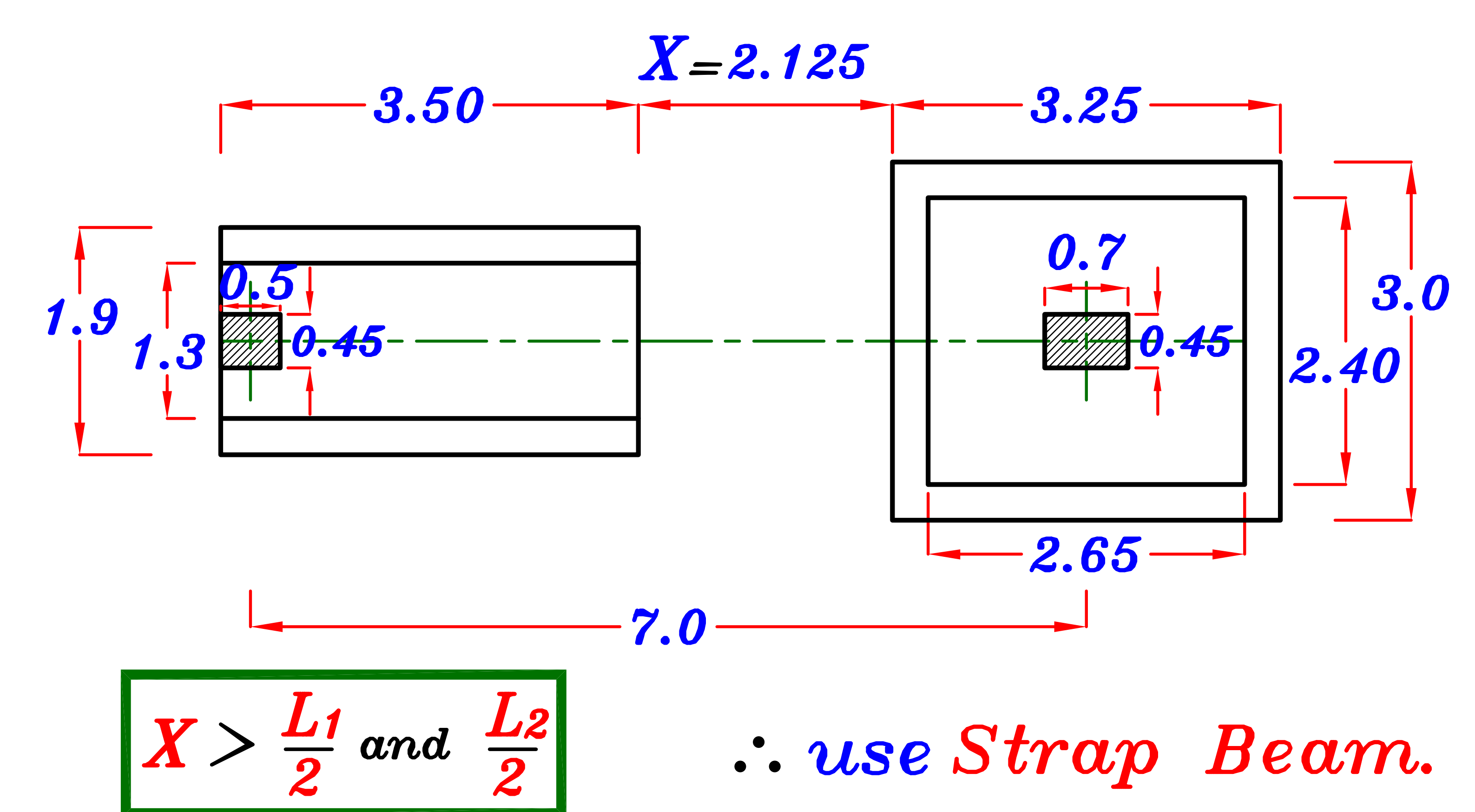
$$L_{2\,P.C.} = B_{2\,P.C.} + 0.25\ m \quad \text{------}(1)$$

$$A_{2\,P.C.} = \frac{R_2}{q_{all}} = \frac{1927.3\ (kN)}{200\ \ (kN/m^2)} = 9.63\ m^2$$

$$A_{2\,P.C.} = B_{2\,P.C.} * L_{2\,P.C.} = 9.63\ m^2 \quad \text{-----}(2)$$

$B_{2\,P.C.} = 3.0\ m$ $\quad$ $L_{2\,P.C.} = 3.25\ m$

$B_{2\,R.C.} = 2.40\ m$ $\quad$ $L_{2\,R.C.} = 2.65\ m$



$$X > \frac{L_1}{2} \text{ and } \frac{L_2}{2}$$

$\therefore$ use Strap Beam.

3 – Dimensionsof the Strap Beam. (Width & depth)

$$w_1 = \frac{R_1 \ (U.L.)}{L_{1\,R.C.}}$$

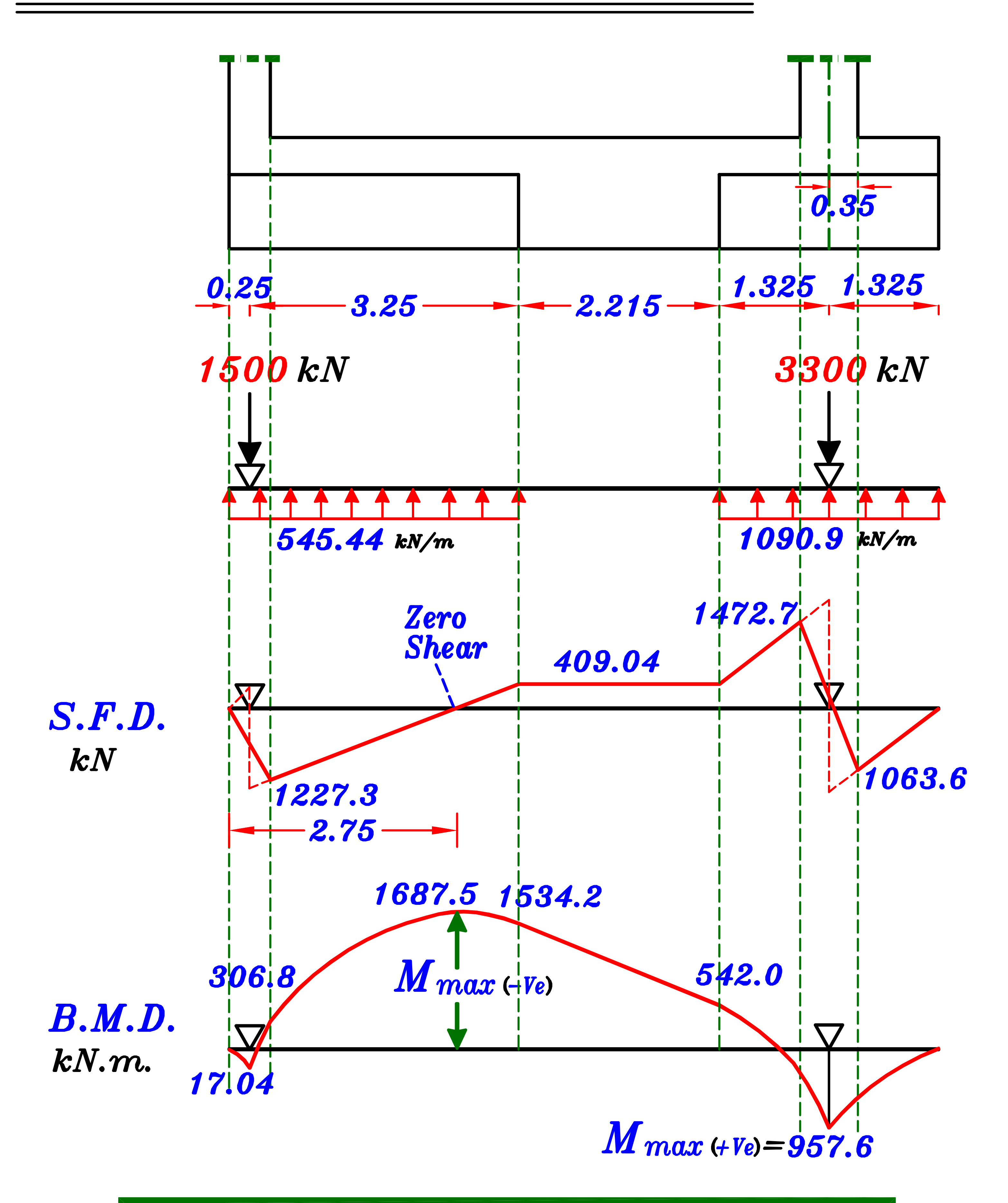
$$w_1 = \frac{1.5 * 1272.7}{3.50} = 545.44 \ (kN/m)$$

$$w_2 = \frac{R_2 \ (U.L.)}{L_{2\,R.C.}}$$

$$w_2 = \frac{1.5 * 1927.3}{2.65} = 1090.9 \ (kN/m)$$

1500
3300
F_1
F_2
1909.05
2890.95
3.50
2.65
w_1 kN/m
w_2 kN/m
545.44 kN/m
1090.9 kN/m

Drawing B.M.D. & S.F.D. For the Beam.



$$\text{Point of Zero Shear } (X_o) = \frac{1500}{545.44} = 2.75 \ m$$

Take $b \nless C_1$ or C_2 Take $b = 0.7\ m$

$\because d = C_1 \sqrt{\dfrac{M_{max}}{F_{cu} * b}}$ Choose $C_1 = 4.5$

$\therefore d = 4.5 \sqrt{\dfrac{1687.5 * 10^6}{25 * 700}} = 1397\ mm$

$t_{R.C.} = d + 70\ mm = 1397 + 70 = 1467\ mm$

$t_{R.C.} = 1500\ mm$ $d = 1430\ mm$

---

4 – Check Shear For Strap Beam. as beams.

S.F.D.
kN

$\frac{d}{2} = 0.715\ m$ 409.04 $Q_{cr.} = 692.7$ 1472.7

1227.3 $Q_{cr.} = 837.3$ $\frac{d}{2} = 0.715\ m$ 1063.6

$$Q_{cr.} = Q_{max.} - w\left(\frac{d}{2}\right) = 1472.7 - 1090.9\left(\frac{1.43}{2}\right) = 692.7\ kN$$

$$Q_{cr.} = Q_{max.} - w\left(\frac{d}{2}\right) = 1227.3 - 545.44\left(\frac{1.43}{2}\right) = 837.3\ kN$$

– Actual Shear Stress.

$$q_{act.} = \frac{Q_{cr.}}{b * d} = \frac{837.3 * 10^3}{700 * 1430} = 0.836\ kN/m^2$$

– Allowable shear stress.

$$q_{cu} = 0.24 \sqrt{\frac{F_{cu}}{\delta_c}} = 0.24 \sqrt{\frac{25}{1.5}} = 0.98\ N\backslash mm^2$$

$$q_{max.} = 0.7 \sqrt{\frac{F_{cu}}{\delta_c}} = 0.7 \sqrt{\frac{25}{1.5}} = 2.85\ N\backslash mm^2$$

$\therefore q_{act.} < q_{cu.} \longrightarrow$ use min. stirrups

Use Stirrups $5 \phi 10 \backslash m'$ 6 branches

5 – Reinforcement of Strap Beam.

B.M.D. kN.m.

1687.5, 1534.2, 306.8, 542.0, 17.04, $M_{max\,(-Ve)}$, $M_{max\,(+Ve)} = 957.6$, (1), (2)

Sec. (1) $M_{max\,(-Ve)} = 1687.5$ kN.m.

$$1430 = C_1 \sqrt{\frac{1687.5 * 10^6}{25 * 700}} \longrightarrow C_1 = 4.60 \longrightarrow J = 0.818$$

$$A_s = \frac{M}{J\,F_y\,d} = \frac{1687.5 * 10^6}{0.818 * 360 * 1430} = 4007.3 \text{ mm}^2$$

Check $A_{s\,min.}$ $A_{s_{req.}} = 4007.3 \text{ mm}^2$

$$\mu_{min.}\,b\,d = \left(0.225 * \frac{\sqrt{F_{cu}}}{F_y}\right) b\,d = \left(0.225 * \frac{\sqrt{25}}{360}\right) 700 * 1430 = 3128.1 \text{ mm}^2$$

$\therefore A_{s_{req.}} > \mu_{min.}\,b\,d$ $\therefore$ Take $A_s = A_{s_{req.}} = 4007.3 \text{ mm}^2$ **11 ϕ 22**

Sec. (2) $M_{max\,(+Ve)} = 957.6$ kN.m.

$$1430 = C_1 \sqrt{\frac{957.6 * 10^6}{25 * 700}} \longrightarrow C_1 = 6.11 \longrightarrow J = 0.826$$

$$A_s = \frac{M}{J\,F_y\,d} = \frac{957.6 * 10^6}{0.826 * 360 * 1430} = 2252 \text{ mm}^2$$

Check $A_{s\,min.}$ $A_{s\,req.} = 2252 \text{ mm}^2$

$$\mu_{min.}\,b\,d = \left(0.225 * \frac{\sqrt{F_{cu}}}{F_y}\right) b\,d = \left(0.225 * \frac{\sqrt{25}}{360}\right) 700 * 1430 = 3128.1 \text{ mm}^2$$

$\therefore \mu_{min.}\,b\,d > A_{s_{req.}}$ Use $A_{s_{min.}}$

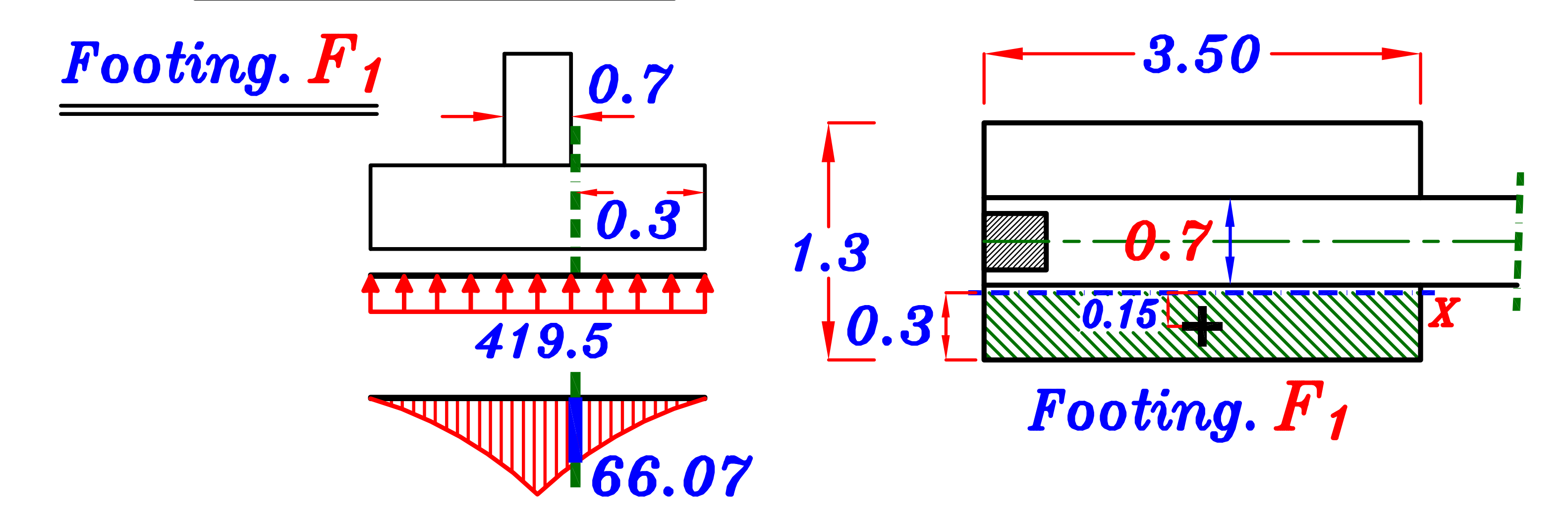
$A_{s_{min.}} = 0.225 * \frac{\sqrt{F_{cu}}}{F_y}\,b\,d = \left(0.225 * \frac{\sqrt{25}}{360}\right) 700 * 1430 = 3128.1$ } الأقل $= 2927.6$

$1.3\,A_{s_{req.}} = 1.3 * 2252 = 2927.6$

st. 360/520 $\frac{0.15}{100}\,b\,d = \frac{0.15}{100} * 700 * 1430 = 1501.5$

} الأكبر $= 2927.6 \text{ mm}^2$ **8 ϕ 22**

6 – Design of Footings. as a strip Footing.

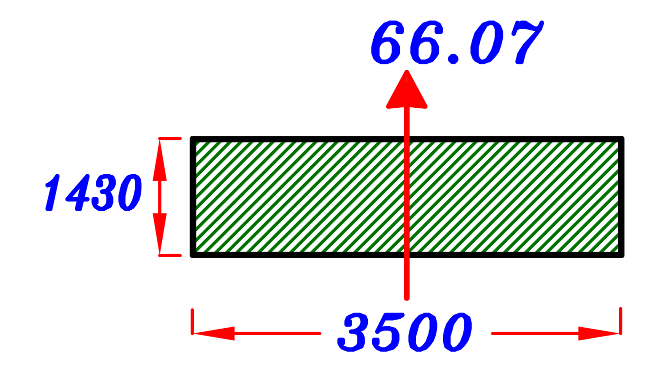


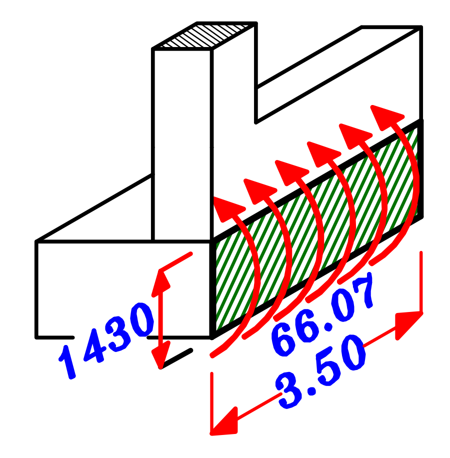
– Actual Normal stress on R.C. Footing (U.L.)

$$F_{1act.} = \frac{R_{1U.L.}}{B_{1R.C.} * L_{1R.C.}} = \frac{1909.05}{3.5 * 1.3} = 419.5 \ kN/m^2$$

– moment = Force * Distance

$$M_{1act.} = 419.5 * 0.3 * 3.5 * 0.15 = 66.07 \ kN/m$$





$$\because \ d = C_1 \sqrt{\frac{M_{act.}}{F_{cu} * b}}$$

Choose $C_1 = 5.0$

$$\therefore \ d = 5.0 \sqrt{\frac{66.07 * 10^6}{25 \ * 3500}} = 137.4 \ mm < 330 \ mm$$

$$t_{R.C.} = d + 70 \ mm = 330 + 70 = 400 \ mm$$

$t_{R.C.} = 400 \ mm$ $\quad$ $d = 330 \ mm$

Check Shear.

$$Q_u = F_{act.} * l * 1.0\,m$$

$$= 419.5 * 0.135 * 1.0\,m = 56.63 \quad kN$$

0.3 0.3 1:1 1:1 $\frac{d}{2}$ $\frac{0.33}{2}$ 0.135

* Calculate Actual shear stress. (q_u)

$$q_u = \frac{Q_u}{b * d} = \frac{56.63 * 10^3}{1000 * 330} = 0.171 \quad N/mm^2$$

* Allowable shear stress. (q_{su})

$$q_{su} = 0.16\sqrt{\frac{F_{cu}}{\gamma_c}} = 0.16\sqrt{\frac{25}{1.5}} = 0.653 \quad N/mm^2$$

$q_u < q_{su}$ ⟶ Safe shear stresses
No need to increase dimensions.

Reinforcement of the Footing.

$$J = 0.826$$

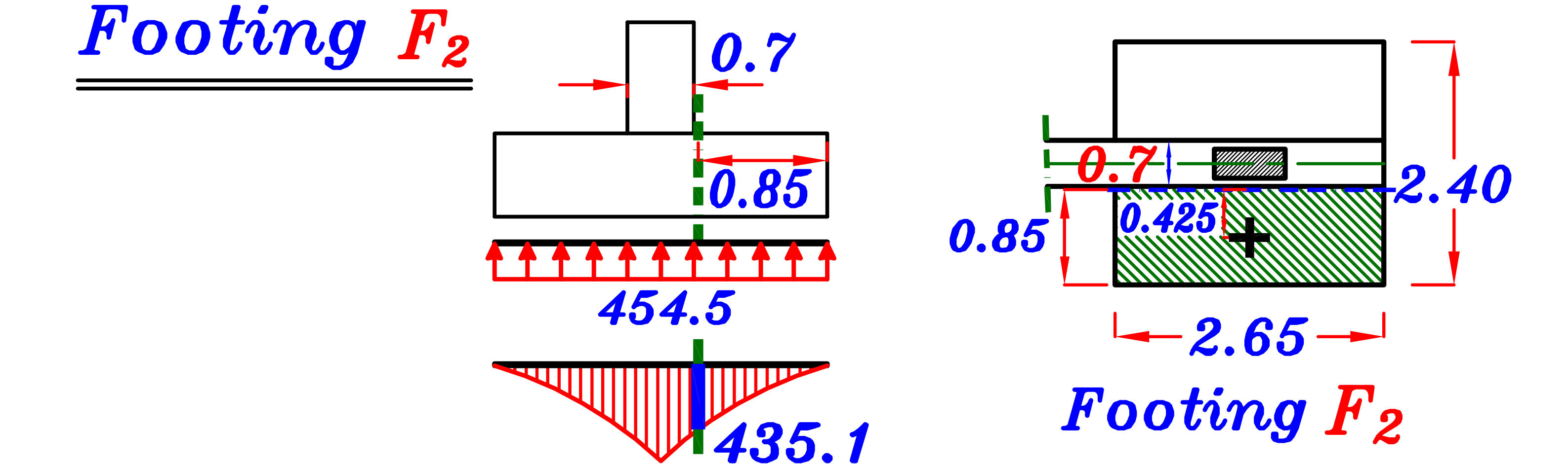
$$A_s = \frac{M_{1act.}}{J\,F_y\,d} = \frac{66.07 * 10^6}{0.826 * 360 * 330} = 673.3 \quad mm^2$$

$$A_s\,(mm^2/m) = \frac{A_s}{B_{R.C.}} = \frac{673.3}{3.50} = 192.3 \quad mm^2/m'$$

Check $A_{s_{min}} = \begin{cases} 1.5\,d = 1.5 * 330 = 495 \\ 5\,\phi\,12/m' = 565.5 \end{cases}$ $565\,mm^2$

$\therefore A_s < A_{s_{min}}$ ⟶ $A_s = 565 \quad mm^2$

$5\,\phi\,12/m'$

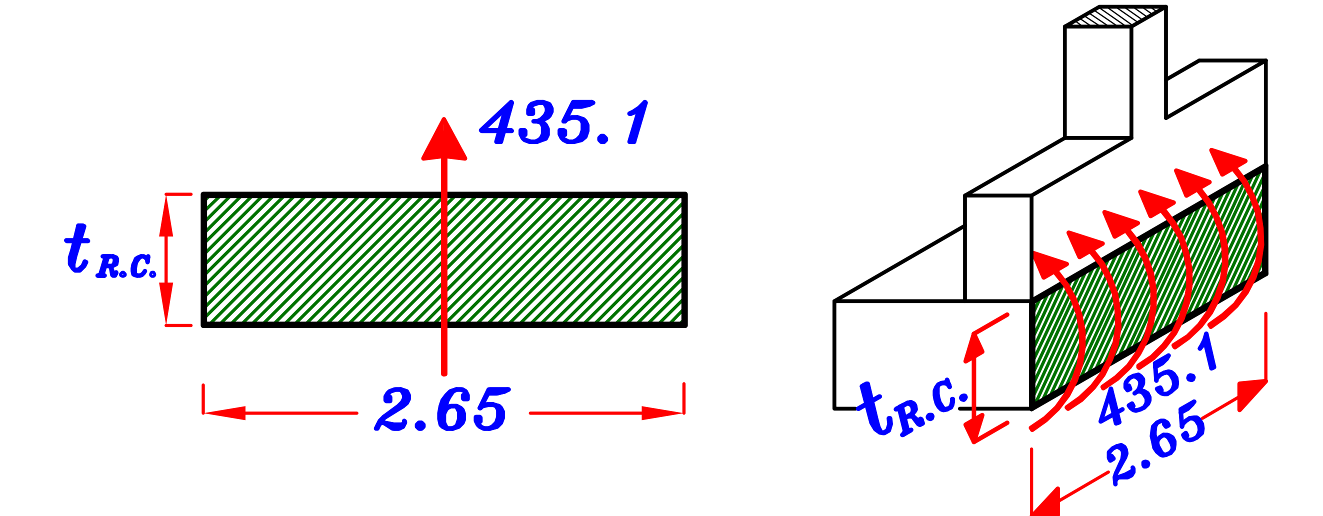


- Actual Normal stress on R.C. Footing (U.L.)

$$F_{2\,act.} = \frac{R_{2\,U.L.}}{B_{2\,R.C.} * L_{2\,R.C.}} = \frac{2890.95}{2.65 * 2.4} = 454.5 \ kN/m^2$$

- moment = Force * Distance

$$M_{2act.} = 454.5 * 0.85 * 2.65 * 0.425 = 435.1 \ kN/m$$



$$\because \ d = C_1 \sqrt{\frac{M_{act.}}{F_{cu} * b}}$$

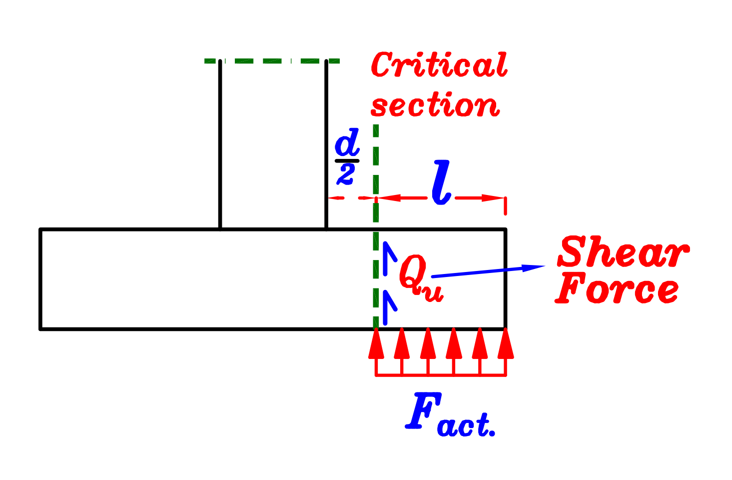
Choose $C_1 = 5.0$

$$\therefore \ d = 5.0 \sqrt{\frac{435.1 * 10^6}{25 * 2650}} = 405.2 \ mm$$

$$t_{R.C.} = d + 70 \ mm = 405.2 + 70 = 475.2 \ mm$$

$t_{R.C.} = 500 \ mm$ **$d = 430 \ mm$**

3 – Check Shear.



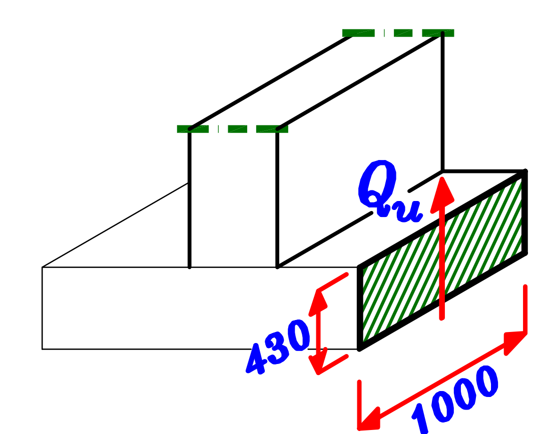
* **Critical section For Shear.**

$$l = z - \frac{d}{2}$$

$$l = 0.85 - \frac{0.43}{2} = 0.63 \ m$$

* **Actual shear Force. (Q_u)**

$$Q_u = F_{act.} * l * 1.0 \ m = 454.5 * 0.63 * 1.0 = 286.3 \ kN$$



* **Actual shear stress. (q_u)**

$$q_u = \frac{Q_u}{b * d} = \frac{286.3 * 10^3}{1000 * 430} = 0.666 \ N/mm^2$$

* **Allowable shear stress. (q_{su})**

$$q_{su} = 0.16 \sqrt{\frac{F_{cu}}{\gamma_c}} = 0.16 \sqrt{\frac{25}{1.5}} = 0.653 \ N/mm^2$$

$$\boxed{q_u \simeq q_{su}} \longrightarrow$$ Safe shear stresses
No need to increase dimensions.

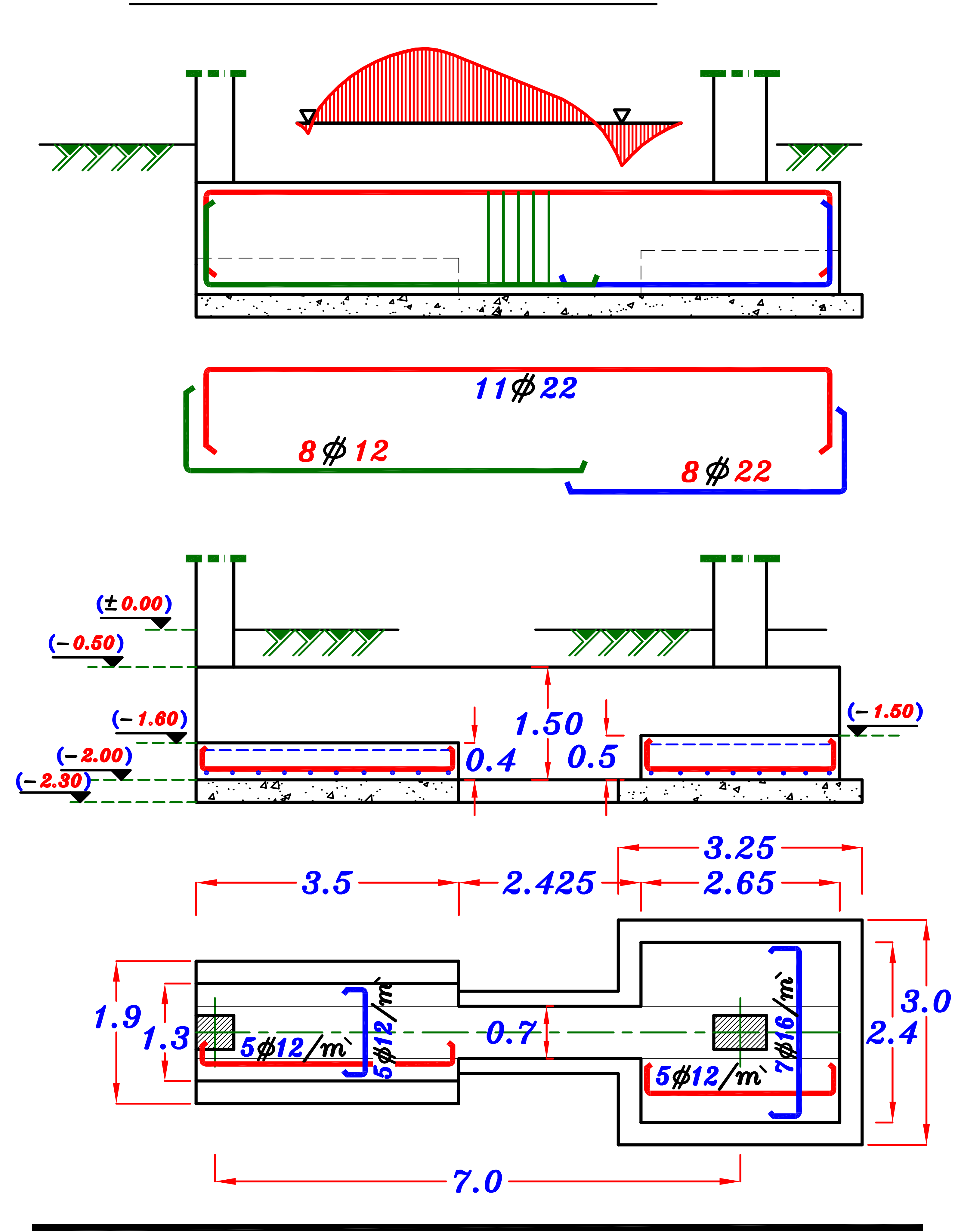
Reinforcement of the Footing.

$$A_s = \frac{M_{2act.}}{J \ F_y \ d} = \frac{435.1 * 10^6}{0.826 * 360 * 430} = 3402.8 \ mm^2$$

$$A_s \ (mm^2/m) = \frac{A_s}{B_{R.C.}} = \frac{3402.8}{2.65} = 1284 \ mm^2/m`$$

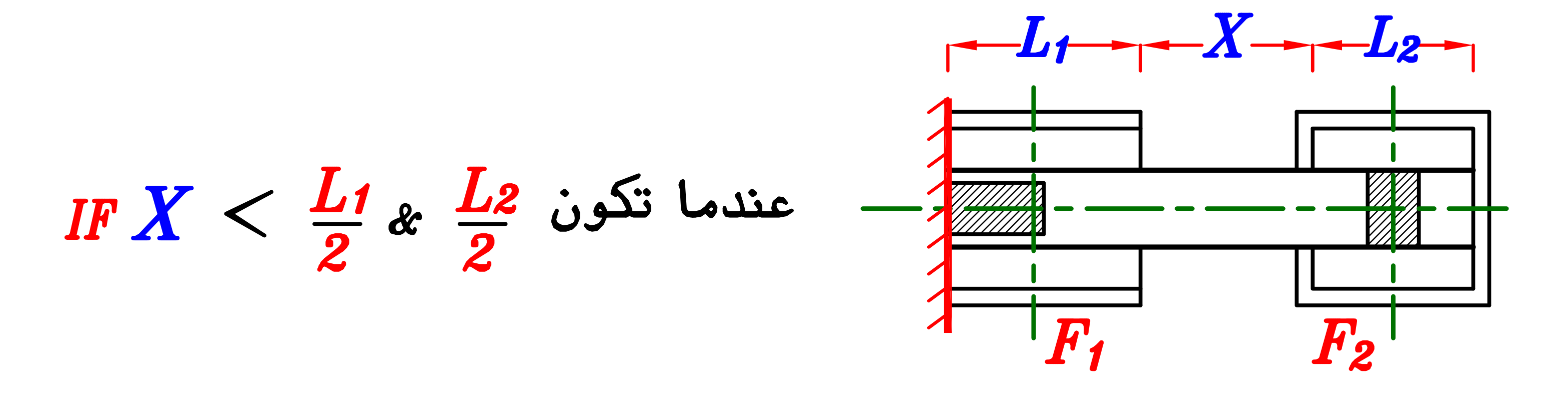
$$\boxed{7 \phi 16 / m`}$$

7- Details of Reinforcement.



2 – Combined Footing For column near an existing (property line)

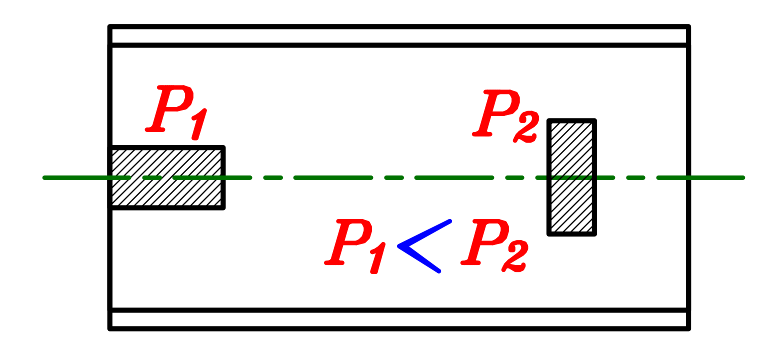
اذا لم ينفع حل ال Strap Beam



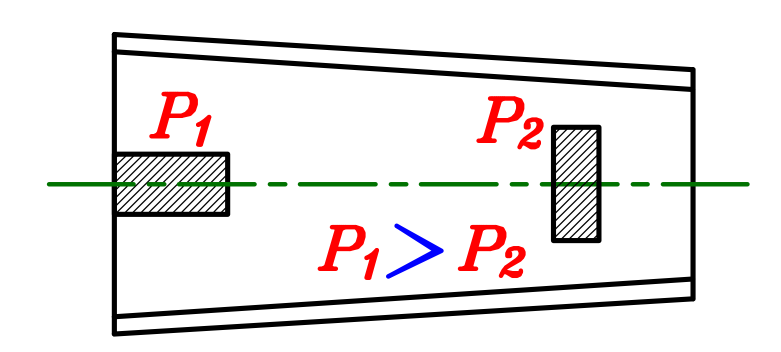
عندما تكون $IF\ X < \frac{L_1}{2}\ \&\ \frac{L_2}{2}$

يتم عمل قاعده مشتركه و يكون شكلها كالاتى :

a- IF $P_1 < P_2$ use **Rectangular** combined Footing.

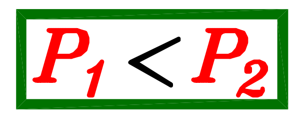


b- IF $P_1 > P_2$ use **Trapezoidal** combined Footing.





Rectangular Combined Footing.



$P_1 < P_2$

قاعده مشتركه مستطيله بجوار حد الجار .

$$R = P_1 + P_2$$

يتم حساب قيمه محصله الاحمال R

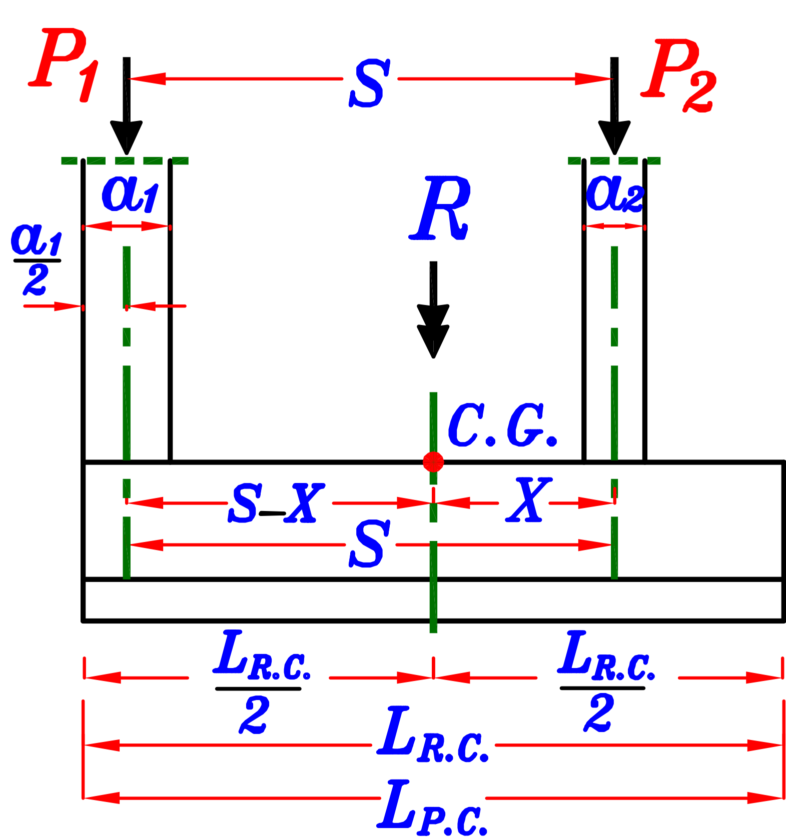
يتم تحديد مكان محصله الاحمال X

$$R * X = P_1 * S \longrightarrow X = \frac{P_1}{R} * S$$

1– Calculate the Footing area. (Width & Length of R.C. Footing.)

$$\frac{L_{R.C.}}{2} = (S-X) + \frac{a_1}{2}$$

$$\rightarrow \boxed{L_{R.C.} = \checkmark}$$



$$\therefore \boxed{L_{P.C.} = L_{R.C.}}$$

و ذلك لانه غير مسموح ببروز الـ P.C. عن الـ R.C. من جهه الجار و بالتالى غير مسموح بالبروز من الجهه الاخرى حتى يظل $C.G._R$ عند $C.G._{P.C.}$ و عند $C.G._{R.C.}$

Calculate the width of the Footing. B

IF $t_{P.C.} \geq 20$ cm get $B_{P.C.}$ From

$$A_{P.C.} = \frac{R_w}{q_{all}} = \checkmark\ m^2 = B_{P.C.} * L_{P.C.} \rightarrow \boxed{B_{P.C.} = \checkmark}$$

$$\boxed{B_{R.C.} = B_{P.C.} - 2\,t_{P.C.}}$$

IF $t_{P.C.} < 20$ cm get $B_{R.C.}$ From

$$A_{R.C.} = \frac{R_w}{q_{all}} = \checkmark\ m^2 = B_{R.C.} * L_{R.C.} \rightarrow \boxed{B_{R.C.} = \checkmark}$$

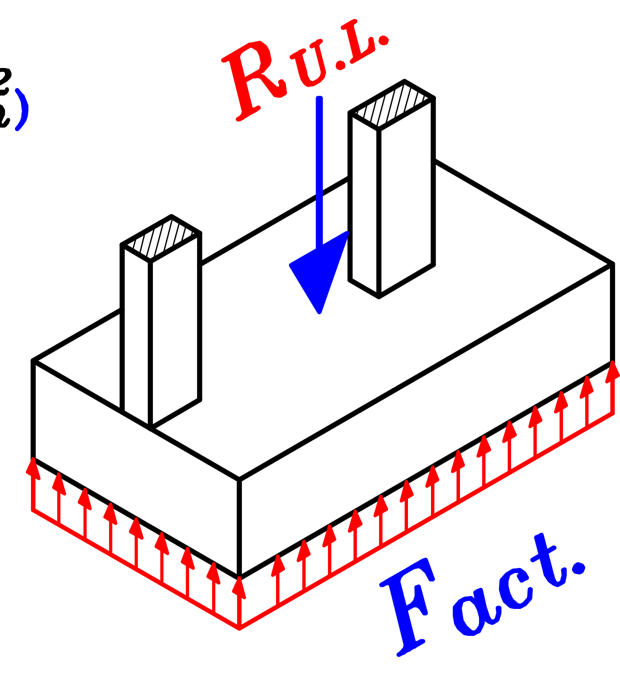
$$\boxed{B_{P.C.} = B_{R.C.} + 2\,t_{P.C.}}$$

2 – Design the critical sections For moment. (Depth of R.C. Footing)

$P_{1U.L.} = 1.5 * P_{1w}$, $P_{2U.L.} = 1.5 * P_{2w}$, $R_{U.L.} = 1.5 * R_w$

– Actual Normal stress on R.C. Footing (U.L.)

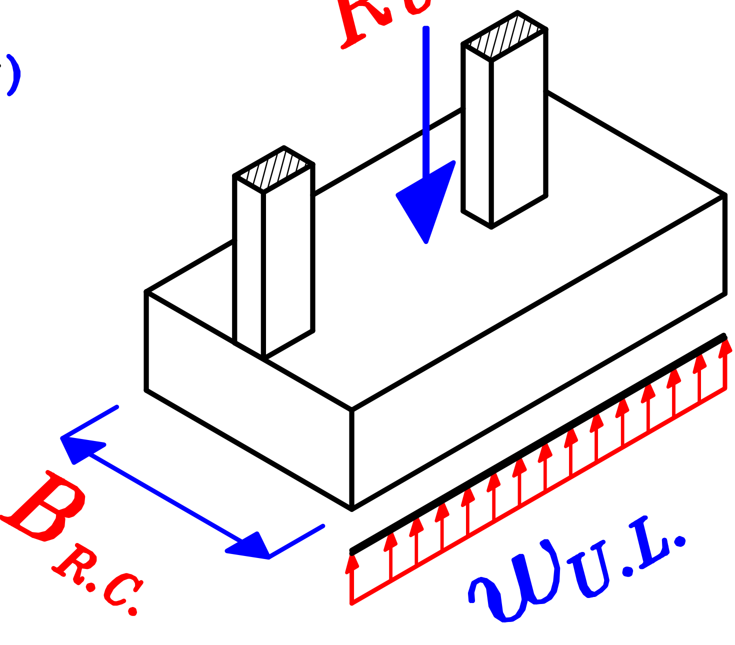
$$F_{act.} = \frac{R_{U.L.}}{B_{R.C.} * L_{R.C.}} \quad (kN/m^2)$$



– Actual Uniform Load on R.C. Footing (U.L.) as a beam.

$B_{R.C.}$ نعتبر أن القاعده عباره عن كمره بعرض

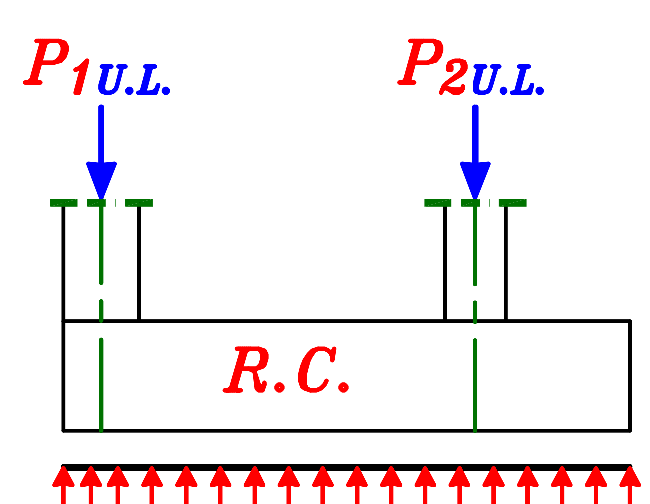
$$w_{U.L.} = \frac{R_{U.L.}}{L_{R.C.}} \quad (kN/m`)$$



Drawing U.L. B.M.D. & S.F.D. on the all R.C. Footing.

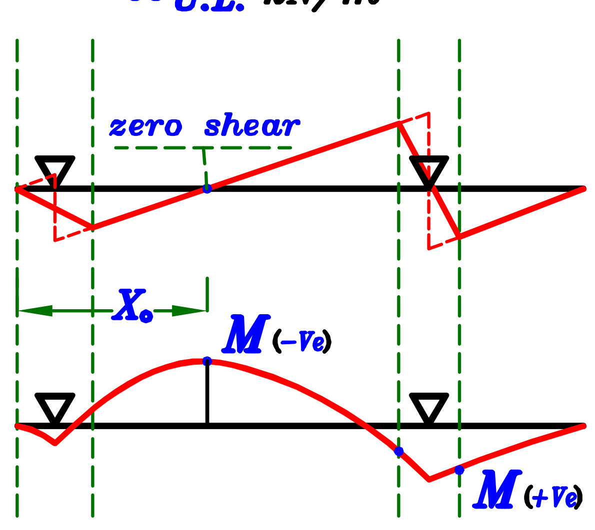
Longitudinal direction.

نعتبر أن القاعده عباره عن كمره بعرض $B_{R.C.}$



يتم رسم B.M.D. , S.F.D.
للقاعده كلها كأنها كمره
بعرض $B_{R.C.}$

و يتم حساب قيم B.M. , S.F.
على وش الاعمده .



S.F.D.

B.M.D.

لتحديد أكبر moment فى منتصف القاعده $M_{(-ve)}$

يتم تحديد مكان نقطه zero shear أى حساب المسافه X_o

$P_{1U.L.} = w_{U.L.} * X_o$ ⟶ $X_o = ✓$ ⟶ $M_{(-ve)} = ✓$

$M_{max.}$ is the bigger moment of $M_{(+ve)}$ & $M_{(-ve)}$

$$d\,(mm) = C_1 \sqrt{\frac{M_{max}\,(kN.m) * 10^6}{F_{cu}\,(N/mm^2) * B_{R.C.}\,(mm)}}$$

Choose $C_1 = (3.5 \rightarrow 5.0)$ Get $d = ✓✓$ (mm)

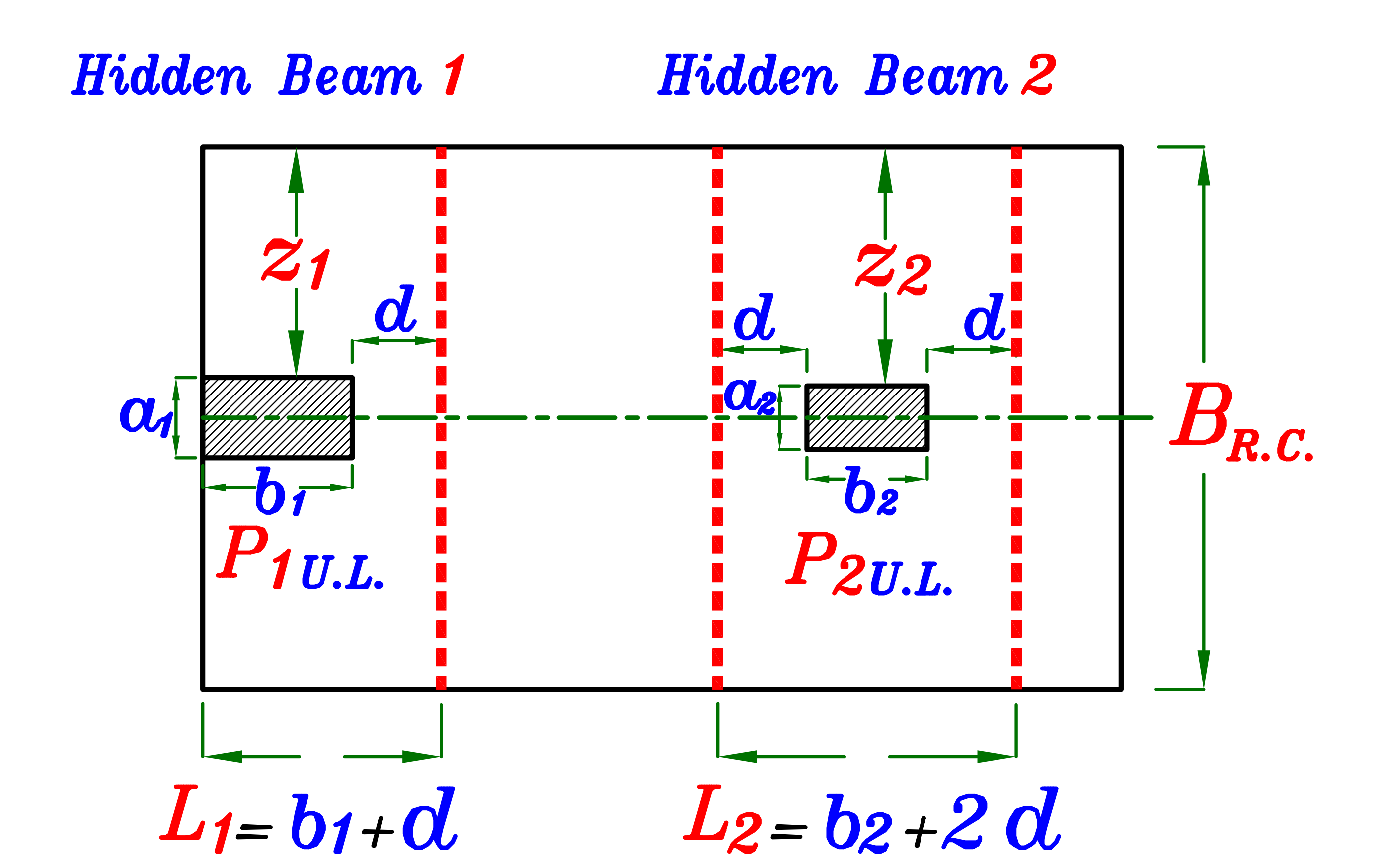
$$t_{R.C.} = d + cover\ (70\ mm)$$

Check depth in Transverse direction. Short direction.

As a Hidden Beam.

(Hidden Beam) نعتبر القاعده أسفل كل عمود كأنها كمره مدفونه

أبعادها أسفل العمود $L * B_{R.C.}$



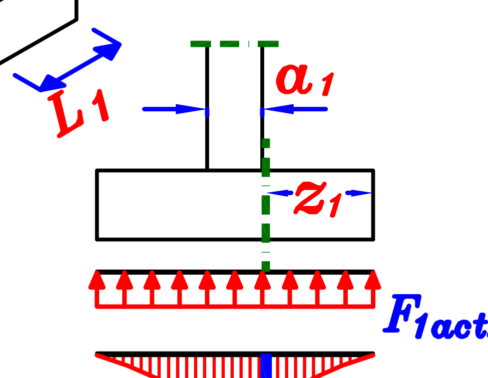


Hidden Beam 1

$$F_{1\,act.} = \frac{P_{1\,U.L.}}{B_{R.C.} * L_1} \quad (kN/m^2)$$

$$Z_1 = \frac{B_{R.C.} - a_1}{2} \quad (m)$$

$$M_{1\,act.} = (F_{1\,act.} * Z_1 * 1.0\,m)\ \frac{Z_1}{2} \quad (kN.m/1.0\,m)$$

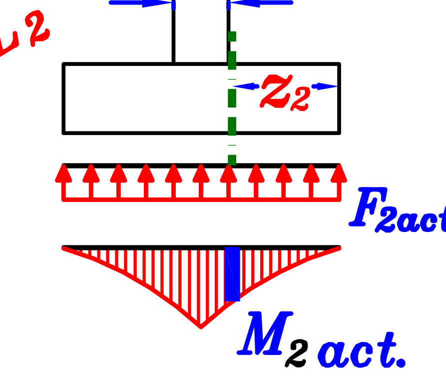


Hidden Beam 2

$$F_{2\,act.} = \frac{P_{2\,U.L.}}{B_{R.C.} * L_2} \quad (kN/m^2)$$

$$Z_2 = \frac{B_{R.C.} - a_2}{2} \quad (m)$$

$$M_{2\,act.} = (F_{2\,act.} * Z_2 * 1.0\,m)\ \frac{Z_2}{2} \quad (kN.m/1.0\,m)$$



Choose M_{bigger} The bigger value of $M_{1\,act.}$ & $M_{2\,act.}$

$$d = C_1 \sqrt{\frac{M_{bigger} * 10^6}{F_{cu} * 1000}} \xrightarrow{\text{Get}} C_1$$

Then Check on $C_1 \nless 3.0$

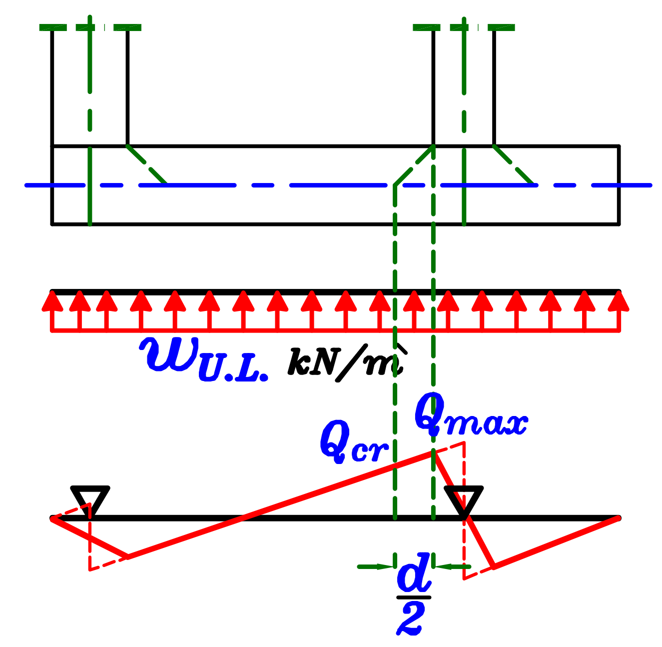
IF $C_1 < 3.0 \longrightarrow$ Increase d

and Recheck the transverse direction.

3 – Check Shear. at long direction.

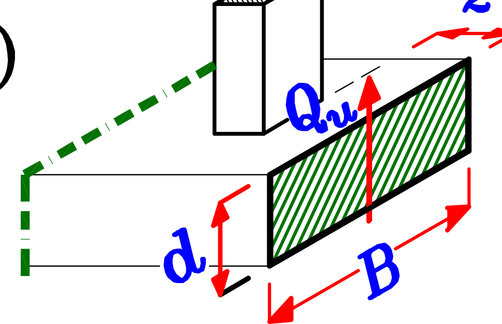
Critical section For Shear.

$Q_{max.}$ على بعد $\frac{d}{2}$ من وش العمود اللى عنده



$$Q_{cr.} = Q_{max.} - w_{U.L.} * \frac{d}{2}$$

* Calculate Actual shear stress. (q_u)



$$q_u = \frac{Q_{cr.}\,(kN) * 10^3}{B\,(mm) * d\,(mm)} \quad (N/mm^2)$$

* Calculate Allowable shear stress. (q_{su})

$$q_{su} = 0.16\sqrt{\frac{F_{cu}}{\gamma_c}} \quad (N/mm^2)$$

* Compare between

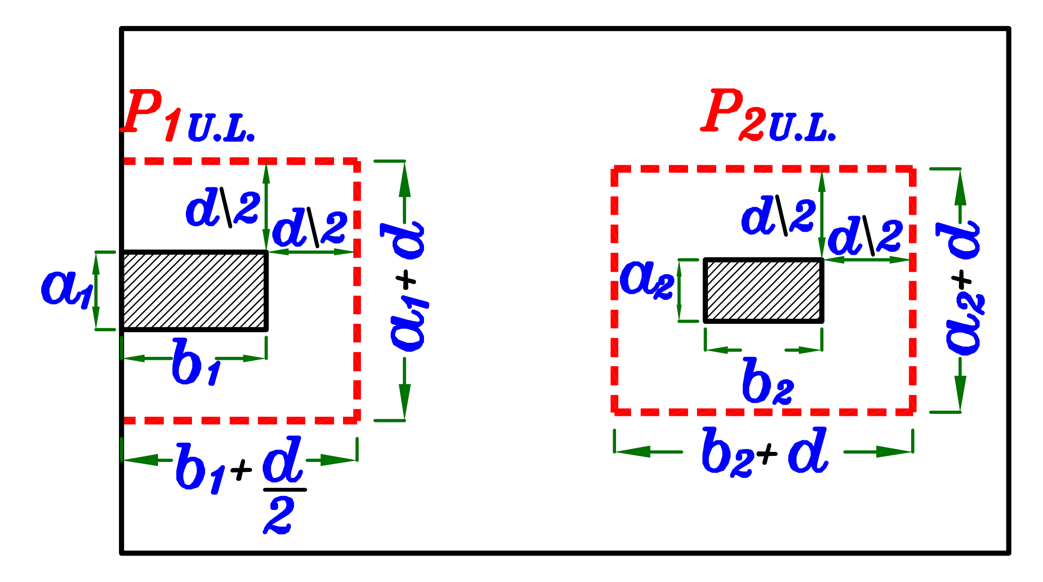
Actual shear stress (q_u) & Allowable shear stress (q_{su})

* IF $q_u \leqslant q_{su}$ ⟶ Safe shear stresses
  No need to increase dimensions.

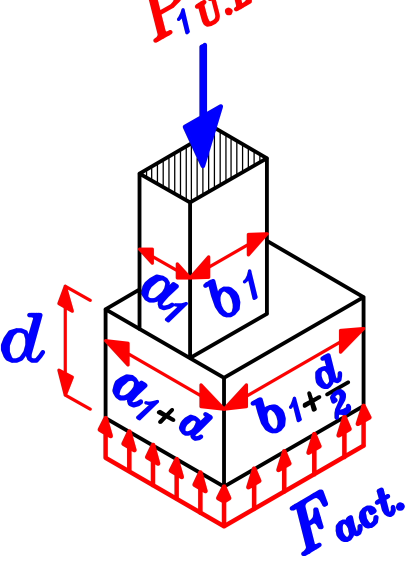
* IF $q_u > q_{su}$ ⟶ UnSafe shear stresses
  We have to increase dimensions.

4 – Check Punching Shear.





Column 1

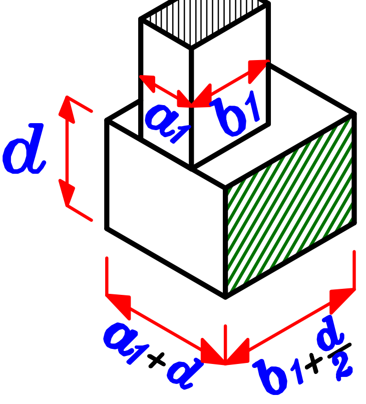


* Calculate Punching Force. (Q_{1p})

$$Q_{1p} = P_{1\,U.L.} - (F_{act.})\left[(a_1+d)(b_1+\frac{d}{2})\right]$$

(kN)

* Calculate Punching shear area. (A_{1p})



المحيط العمق

$$A_{1p} = \left[(a_1+d) + 2\,(b_1+\frac{d}{2})\right] * d$$

(mm^2)

* Calculate Actual Punching shear stress. q_{1pu}

$$q_{1pu} = \frac{Q_{1p}\ (kN) * 10^3}{\left[(a_1+d)+2\,(b_1+\frac{d}{2})\right] * d\ (mm^2)}$$

(N/mm^2)

Column 2

* Calculate Punching Force. (Q_{2p})

$$Q_{2p} = P_{2\,U.L.} - (F_{act.})\left[(a_2+d)(b_2+d)\right]$$

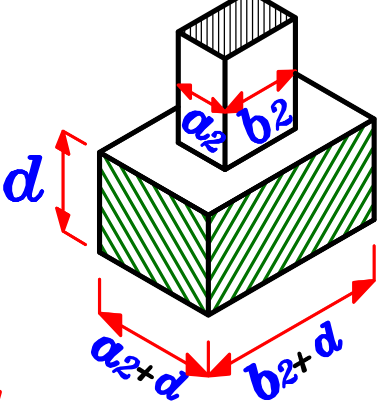
(kN)

* Calculate Punching shear area. (A_{2p})

المحيط   العمق

$$A_{2p} = \left[2(a_2+d) + 2(b_2+d)\right] * d$$

(mm^2)



* Calculate Actual Punching shear stress. q_{2pu}

$$q_{2pu} = \frac{Q_{2p}\ (kN) * 10^3}{\left[2(a_2+d) + 2(b_2+d)\right] * d\ \ (mm^2)}$$

(N/mm^2)

Choose $q_{pu_{max}}$ the bigger value of q_{1pu} & q_{2pu}

* Calculate allowable Punching shear stress. q_{pcu}

نأخذ القيمه الاقل من الاربع قيم التاليه .

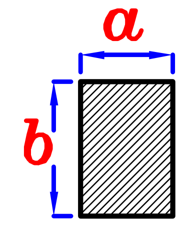
$$q_{pcu} = 0.8\left(\frac{\alpha\, d}{b_o} + 0.2\right)\sqrt{\frac{F_{cu}}{\gamma_c}}$$

$\alpha = 4$ Interior Col.
$\alpha = 3$ Edge Col.
$\alpha = 2$ Corner Col.

Take b_o For the Edge column to get smaller q_{pcu}

Take $\alpha = 3$ For the Edge column to get smaller q_{pcu}

$$q_{pcu} = 0.316\left(0.5 + \frac{a}{b}\right)\sqrt{\frac{F_{cu}}{\gamma_c}} \quad (N/mm^2)$$



a هو العرض الصغير للعمود

$$q_{pcu} = 0.316\sqrt{\frac{F_{cu}}{\gamma_c}} \quad (N/mm^2)$$

$$q_{pcu} = 1.60 \quad (N/mm^2)$$

* Compare between

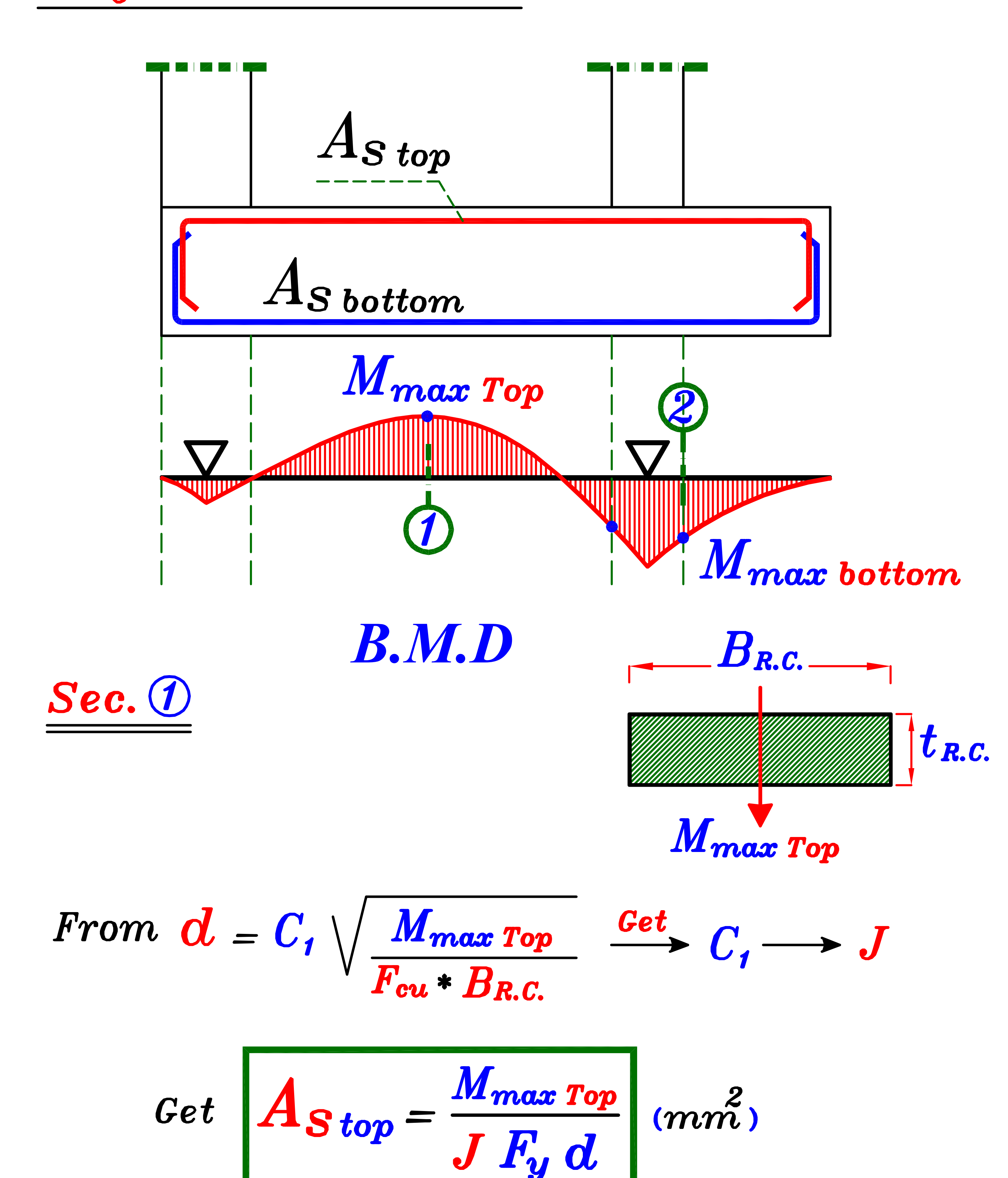
Actual punching shear stress $(q_{pu_{max}})$ & Allowable punching shear stress (q_{pcu})

* IF $q_{pu_{max}} \leq q_{pcu}$ ⟶ Safe punching shear.
No need to increase dimensions.

* IF $q_{pu_{max}} > q_{pcu}$ ⟶ UnSafe punching shear.
We have to increase dimensions.

5- Reinforcement of the Footing.

Longitudinal direction.



$$d = C_1 \sqrt{\frac{M_{max\ Top}}{F_{cu} * B_{R.C.}}} \xrightarrow{Get} C_1 \longrightarrow J$$

Get $$A_{s\ top} = \frac{M_{max\ Top}}{J\ F_y\ d} \quad (mm^2)$$

Check $A_{s\,min}$

$$A_{s\,min}\ (mm^2/m) = \begin{cases} 1.5\, d\ (mm) \\ 5 \phi 12 / m' \end{cases} \text{الأكبر}$$

IF $A_{s\,top} \geqslant A_{s\,min} \longrightarrow$ o.k.

IF $A_{s\,top} < A_{s\,min} \longrightarrow$ Take $A_s = A_{s\,min}$

Sec. ②

$M_{max\ bottom}$

$t_{R.C.}$

$B_{R.C.}$

From $d = C_1 \sqrt{\dfrac{M_{max\ bottom}}{F_{cu} * B_{R.C.}}}$

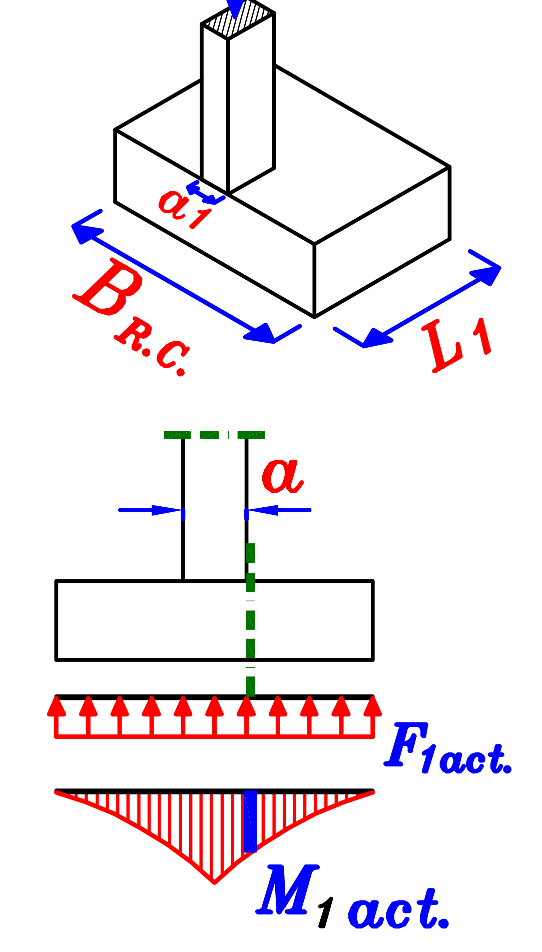
$\xrightarrow{Get} C_1 \longrightarrow J$

Get $$A_{s\,bottom} = \frac{M_{max\ bottom}}{J\, F_y\, d}\ (mm^2)$$

Check $A_{s\,min}$

$$A_{s\,min}\ (mm^2/m) = \begin{cases} 1.5\, d\ (mm) \\ 5 \phi 12 / m' \end{cases} \text{الأكبر}$$

Transverse direction. Short direction.

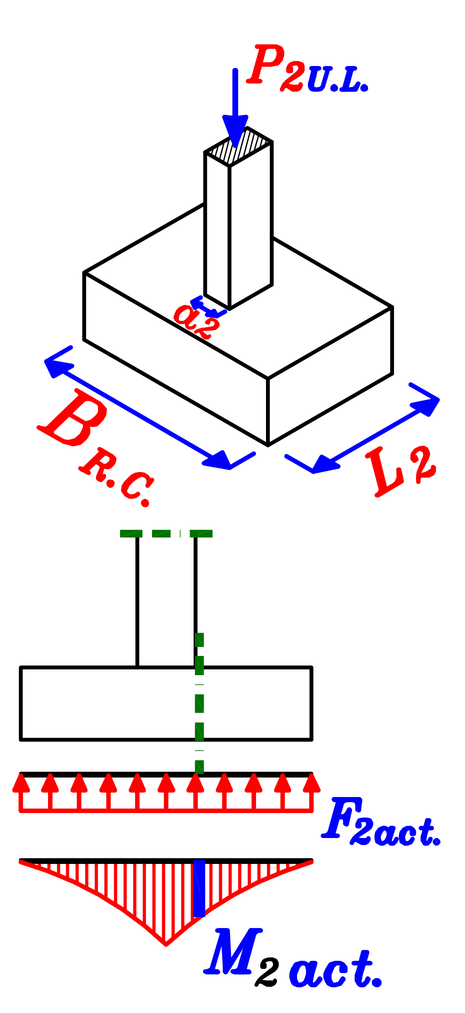


Hidden Beam 1

From $d = C_1 \sqrt{\dfrac{M_{1act.}}{F_{cu} * 1000}}$ $\xrightarrow{Get} C_1 \longrightarrow J$

Get $$A_{s1} = \frac{M_{1act.}}{J\, F_y\, d} \quad (mm^2/m`)$$

Check $A_{s_{min}}$



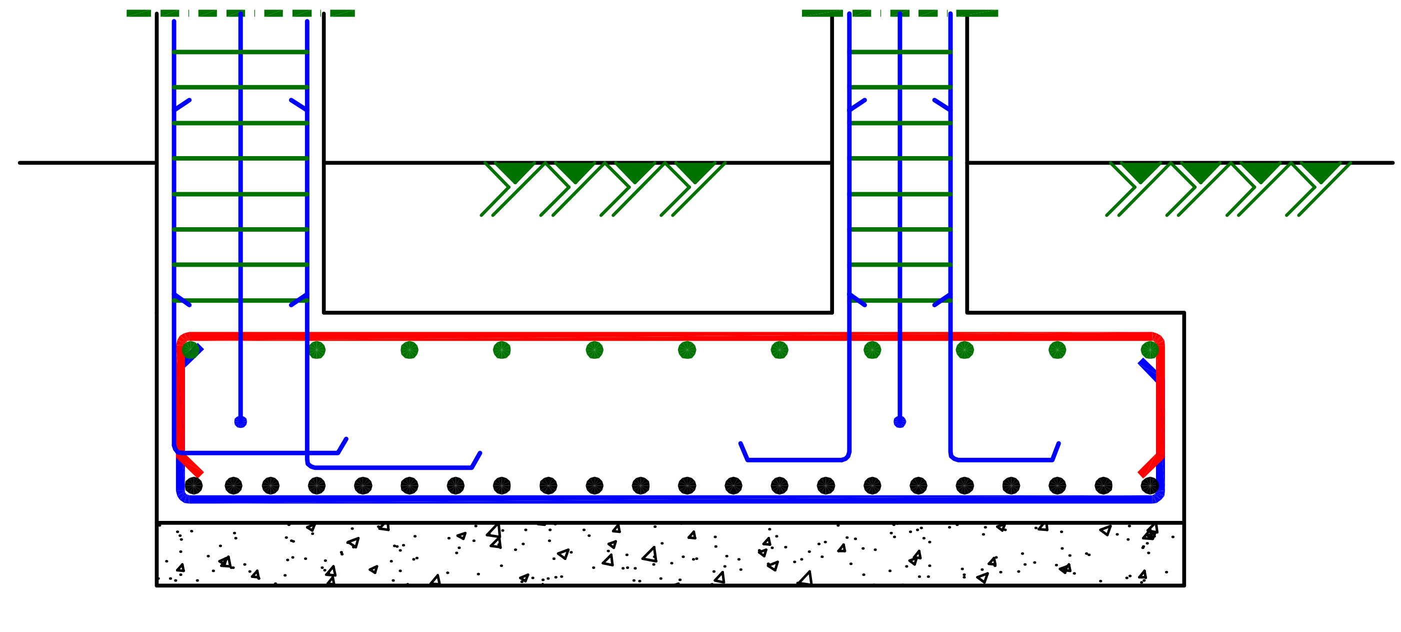
Hidden Beam 2

From $d = C_1 \sqrt{\dfrac{M_{2act.}}{F_{cu} * 1000}}$ $\xrightarrow{Get} C_1 \longrightarrow J$

Get $$A_{s2} = \frac{M_{2act.}}{J\, F_y\, d} \quad (mm^2/m`)$$

Check $A_{s_{min}}$

6- Details of Reinforcement.



Sec X-X

A_{s2}

$5\phi 12/m'$

A_{s2}

X

X

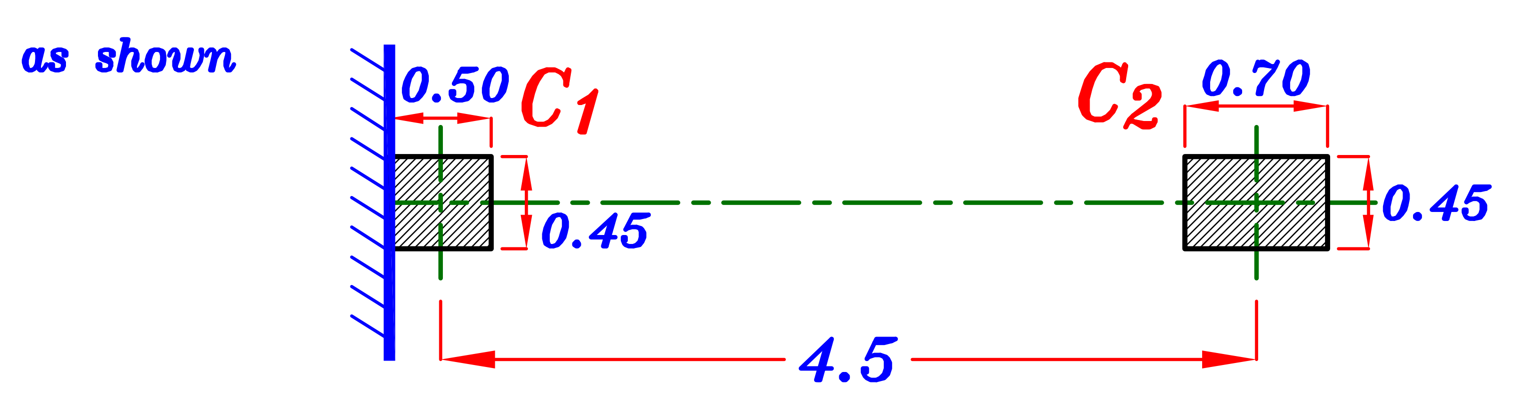
L_1

L_2

Plan

Example.

It is required to design Footings to support a property line column C_1 (45 * 50) cm. and carrying working load 1000 kN and interior column C_2 (45 * 70) cm. and carrying working load 2200 kN the spacing between the C.L. of the two columns is 4.5 m as shown



and the allowable net bearing capacity in the Footing site is 200 kN/m^2. ($F_{cu} = 25\ N/mm^2$, $F_y = 360\ N/mm^2$).
and draw details of RFT. to scale 1:50

Solution.

Data given.

Column C_1 dimensions (450 * 500) mm

P_1 (working) = 1000 kN $\qquad$ P_1 (U.L.) = 1000 * 1.5 = 1500 kN

Column C_2 dimensions (450 * 700) mm

P_2 (working) = 2200 kN $\qquad$ P_2 (U.L.) = 2200 * 1.5 = 3300 kN

$R_{(working)} = P_1 + P_2 = 3200$ kN

$R_{(U.L.)} = 1.5 * 3200 = 4800$ kN

Bearing capacity of the soil = $q_{all} = 200\ kN/m^2$

$F_{cu} = 25\ N/mm^2$ $\qquad$ $F_y = 360\ N/mm^2$

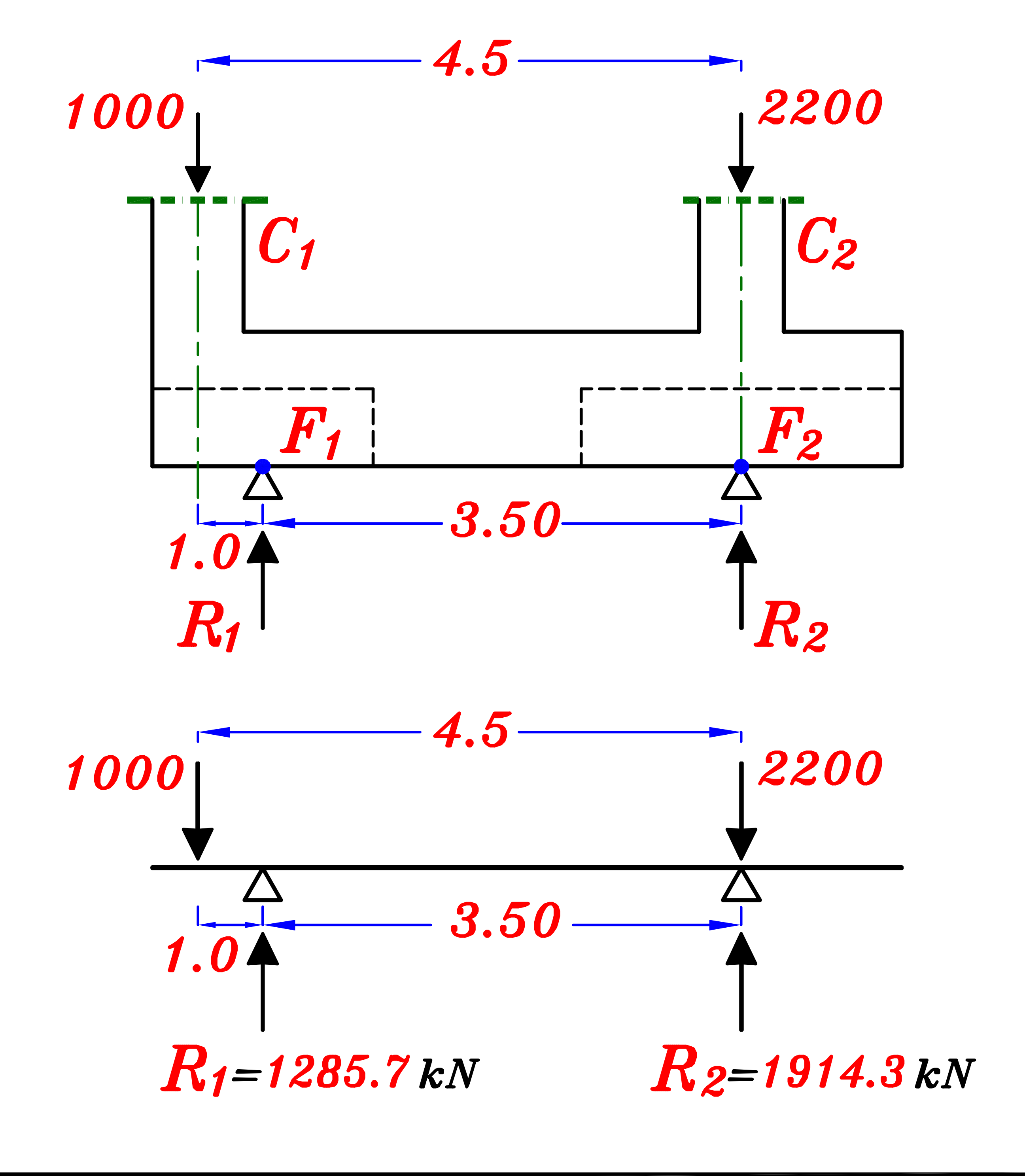
For property line use

Strap Beam or Combined Footing.

Start with Strap Beam.

1- Calculate the Footing area. (Width & Length of R.C. Footings.)

Take $e = 0.1 + 0.2\,(S) = 0.1 + 0.2\,(4.5) = 1.0\ m$



Footing F_1

Choose $t_{P.C.} = 30\ cm > 20\ cm$

0.5

L_1

F_1

0.25 1.0

$$L_{1\,P.C.} = 2\left(e + \frac{C_1}{2}\right) = 2\,(1.0 + 0.25) = 2.50\ m$$

get $B_{1\,P.C.}$ From $A_{P.C.} = \frac{R_1}{q_{all}} = A_{P.C.} = B_{1P.C.} * L_{1\,P.C.}$

$$A_{P.C.} = \frac{1285.7}{200} = B_{1P.C.} * 2.50 \longrightarrow B_{1P.C.} = 2.57\ m$$

$B_{1P.C.} = 2.60\ m$	$L_{1P.C.} = 2.50\ m$
$B_{1R.C.} = 2.0\ m$	$L_{1R.C.} = 2.50\ m$

Footing F_2

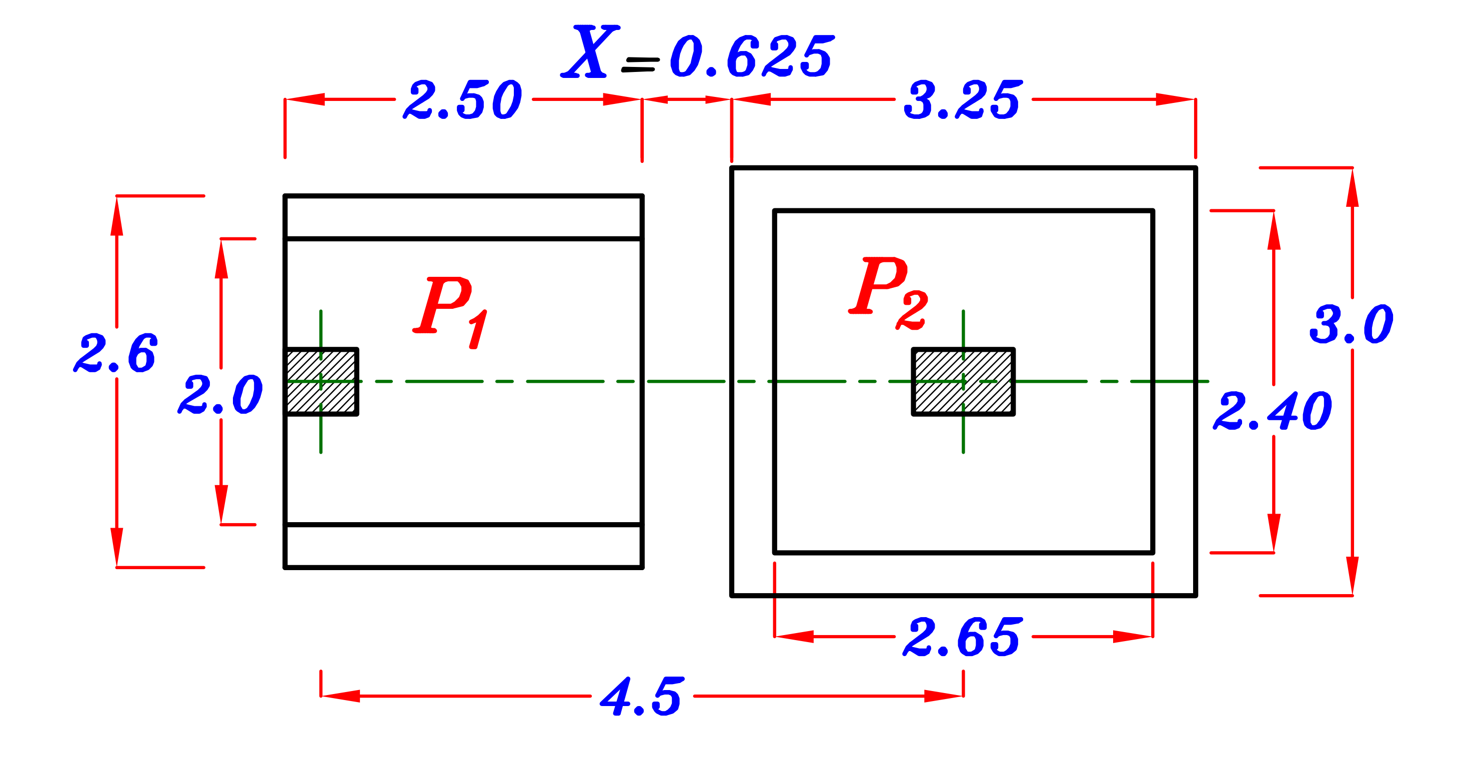
$$L_{2P.C.} - B_{2P.C.} = b - a = 0.70 - 0.45 = 0.25\ m$$

$$L_{2P.C.} = B_{2P.C.} + 0.25\ m \quad \text{------} (1)$$

$$A_{2P.C.} = \frac{R_2}{q_{all}} = \frac{1914.3\ (kN)}{200\ \ (kN/m^2)} = 9.57\ m^2$$

$$A_{2P.C.} = B_{2P.C.} * L_{2P.C.} = 9.57\ m^2 \quad \text{-----} (2)$$

$B_{2P.C.} = 3.0\ m$	$L_{2P.C.} = 3.25\ m$
$B_{2R.C.} = 2.40\ m$	$L_{2R.C.} = 2.65\ m$

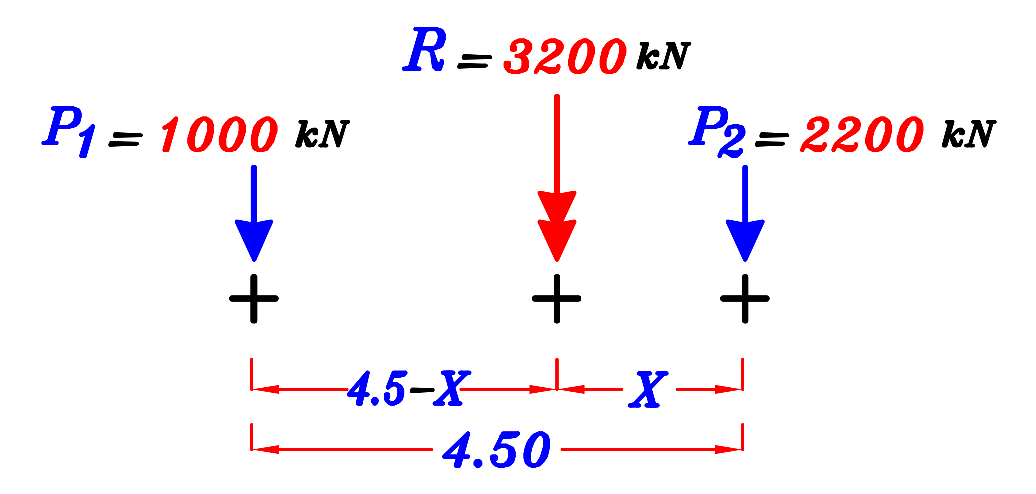


$X = 0.625\ m \quad \therefore \quad \boxed{X < \frac{L_1}{2} \text{ or } \frac{L_2}{2}}$

$\because \quad \boxed{P_1 < P_2}$

$\therefore$ use Rectangular Combined Footing.

1 – Calculate the Footing area. (Width & Length of R.C. Footing)



$$X = \frac{P_1}{R} * S = \frac{1000}{3200} * 4.5 = 1.40 \ m$$

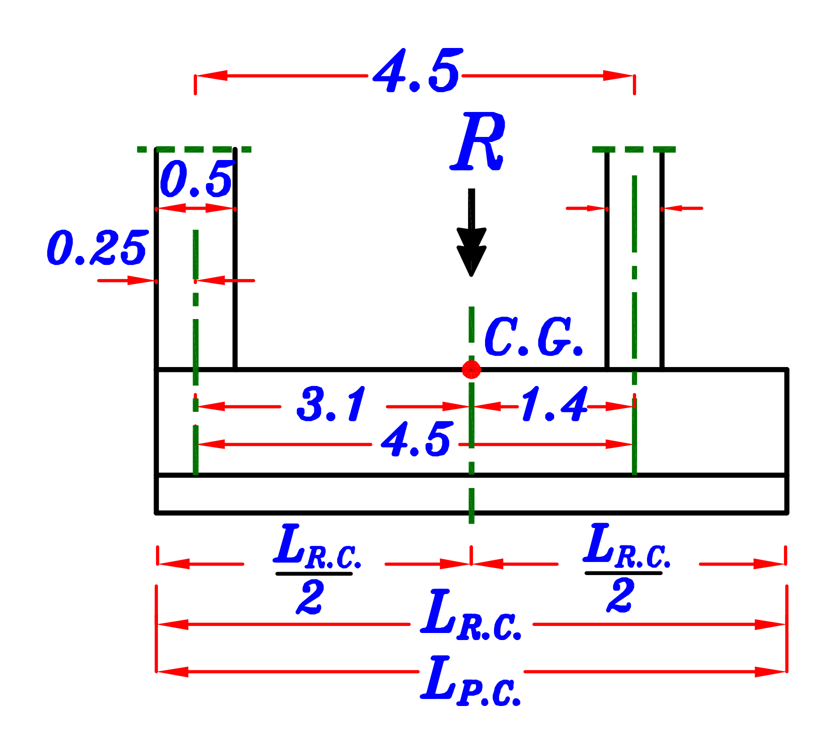
$$R = P_1 + P_2 = 1000 + 2200 = 3200 \ kN$$

$$L_{R.C.} = 2(3.1 + 0.25)$$

$$= 6.70 \ m$$

$$L_{R.C.} = 6.70 \ m$$

$$L_{P.C.} = 6.70 \ m$$



Calculate the width of the Footing. B

$$A_{P.C.} = \frac{R_w}{q_{all}} = \frac{3200}{200} = 16.0 \ m^2 = B_{P.C.} * L_{P.C.} = B_{P.C.} * 6.70$$

$$B_{P.C.} = 2.39 \ m$$

$$B_{P.C.} = 2.40 \ m$$

$$B_{R.C.} = 1.80 \ m$$

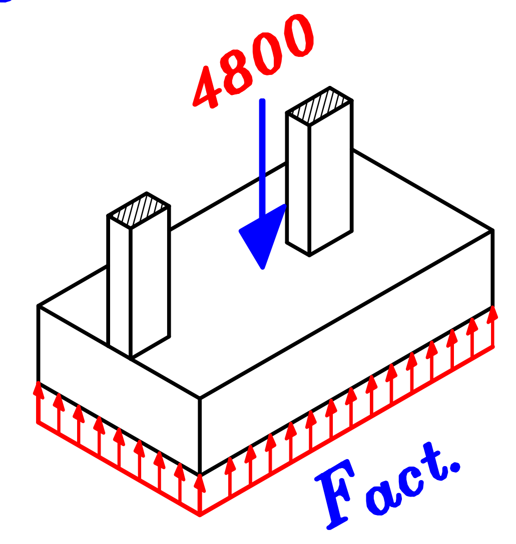
2- Design the critical sections For moment. (Depth of R.C. Footing)

$P_{1\,U.L.} = 1.5 * 1000 = 1500$ kN

$P_{2\,U.L.} = 1.5 * 2200 = 3300$ kN

$R_{U.L.} = 1.5 * 3200 = 4800$ kN

- Actual Normal stress on R.C. Footing (U.L.)

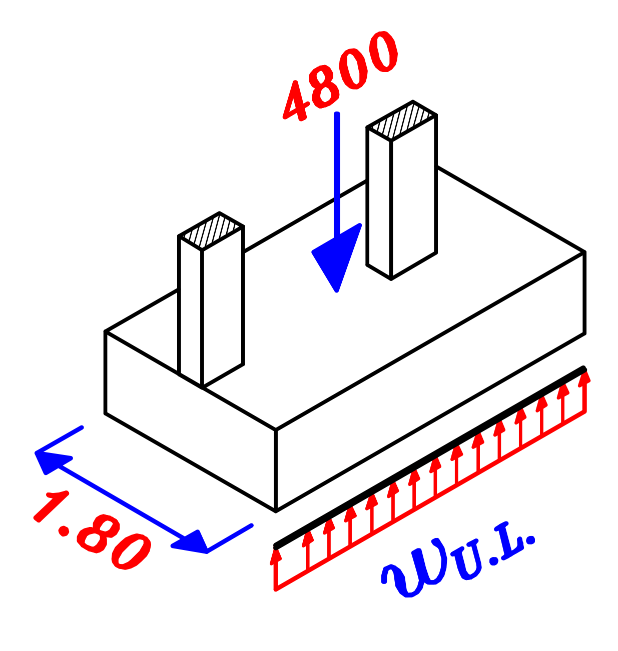


$$F_{act.} = \frac{R_{U.L.}}{B_{R.C.} * L_{R.C.}}$$

$$F_{act.} = \frac{4800}{1.8 * 6.7} = 398.0 \ kN/m^2$$

$$\boxed{F_{act.} = 398.0} \quad kN/m^2$$

- Actual Uniform Load on R.C. Footing (U.L.) as a beam.



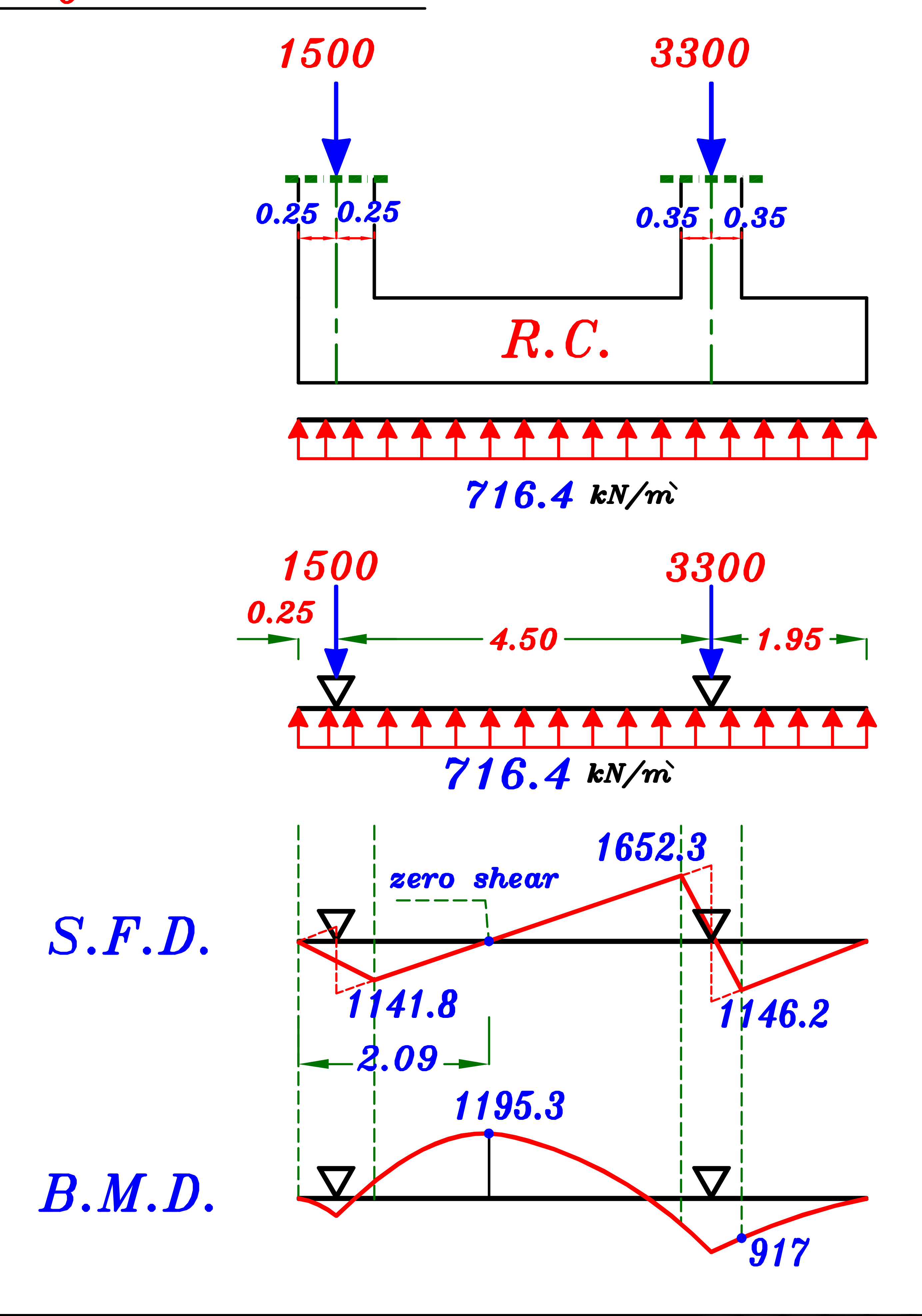
$$w_{U.L.} = \frac{R_{U.L.}}{L_{R.C.}} \quad (kN/m`)$$

$$w_{U.L.} = \frac{4800}{6.7} = 716.4 \ kN/m`$$

$$\boxed{w_{U.L.} = 716.4} \quad kN/m`$$

Drawing U.L. B.M.D. & S.F.D. on the all R.C. Footing.

Longitudinal direction.



$\because \; d = C_1 \sqrt{\dfrac{M_{act.}}{F_{cu} * b}}$ **Choose $C_1 = 5.0$**

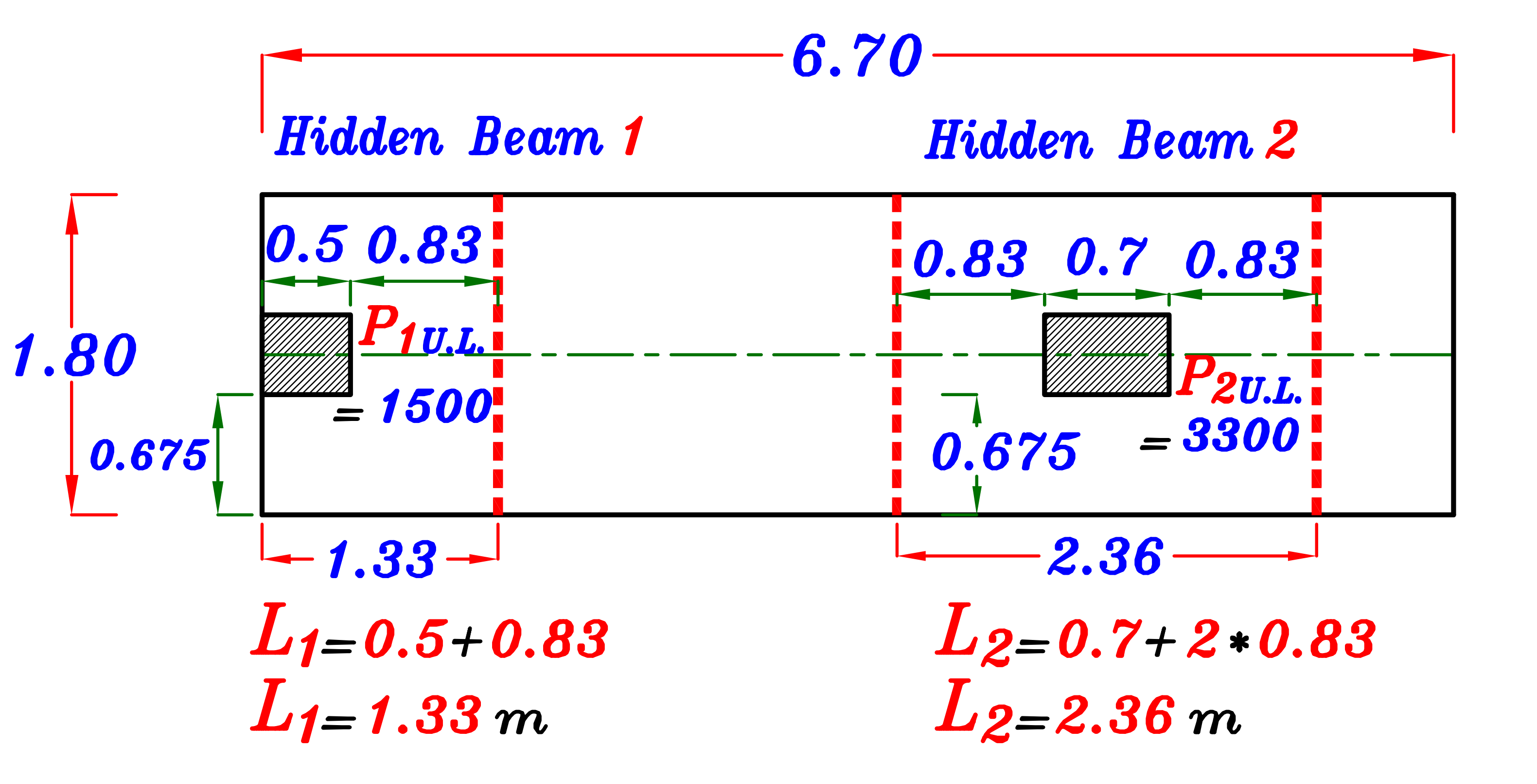
$\therefore \; d = 5.0 \sqrt{\dfrac{1195.3 * 10^6}{25 * 1800}} = 814.9 \; mm$

$t_{R.C.} = d + 70 \; mm = 814.9 + 70 = 884.9 \; mm$

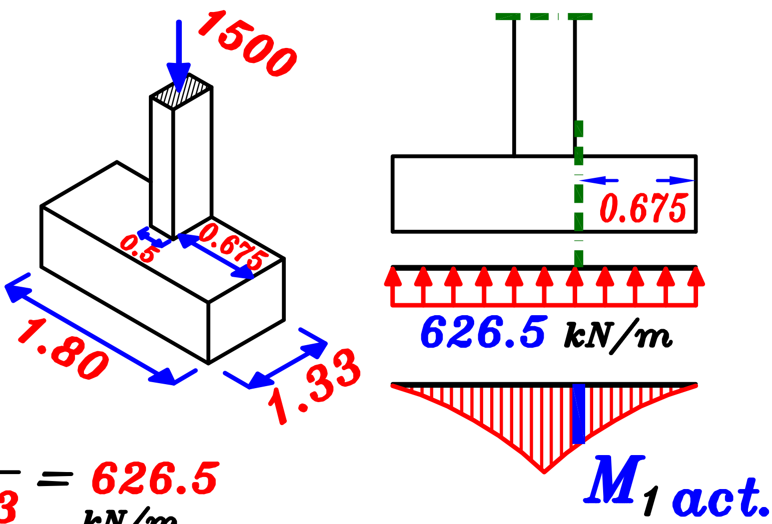
$t_{R.C.} = 900 \; mm$ $d = 830 \; mm$

Check depth in Transverse direction.

As a Hidden Beam.



Hidden Beam 1

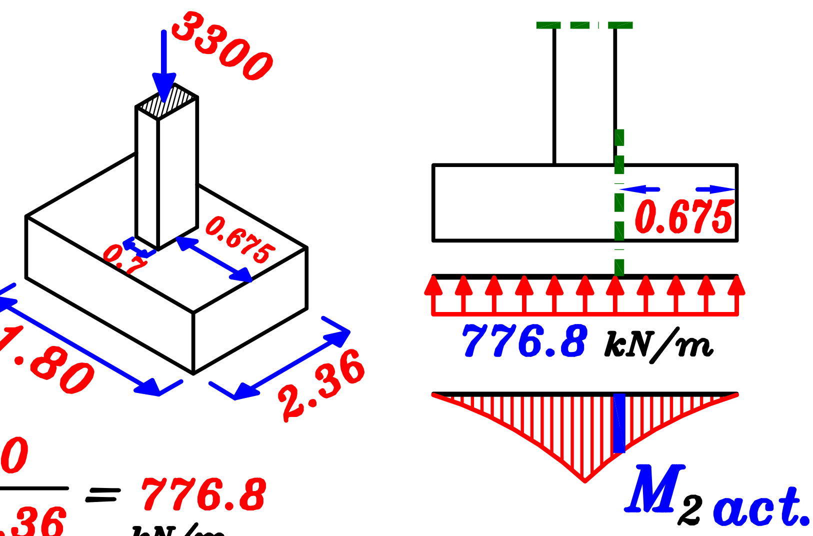


$$F_{1act.} = \frac{P_{1\,U.L.}}{B_{R.C.} * L_1} = \frac{1500}{1.8 * 1.33} = 626.5 \ kN/m$$

$$M_{1act.} = (626.5 * 0.675 * 1.0\,m)\ \frac{0.675}{2}$$

$$M_{1act.} = 142.7 \ kN.m/m$$

Hidden Beam 2



$$F_{2act.} = \frac{P_{2\,U.L.}}{B_{R.C.} * L_2} = \frac{3300}{1.8 * 2.36} = 776.8 \ kN/m$$

$$M_{2act.} = (776.8 * 0.675 * 1.0\,m)\ \frac{0.675}{2}$$

$$M_{2act.} = 176.9 \ kN.m/m$$

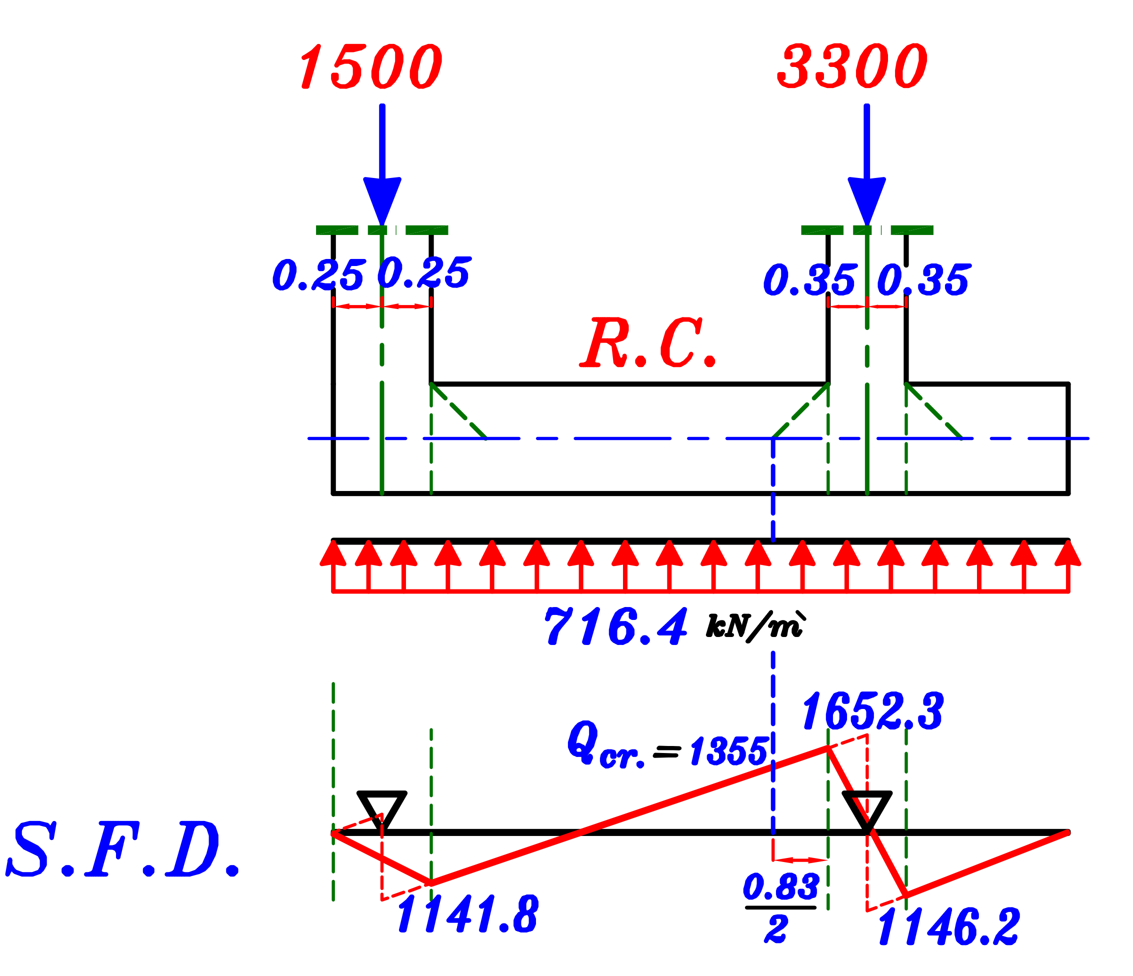
M_{bigger} From $M_{1\,act.}$ & $M_{2\,act.}$

$$M_{bigger} = 176.9 \ kN.m/m$$

$$830 = C_1 \sqrt{\frac{176.9 * 10^6}{25 * 1000}} \longrightarrow C_1 = 9.86 > 3.0 \ \therefore ok.$$

3 – Check Shear at long direction.

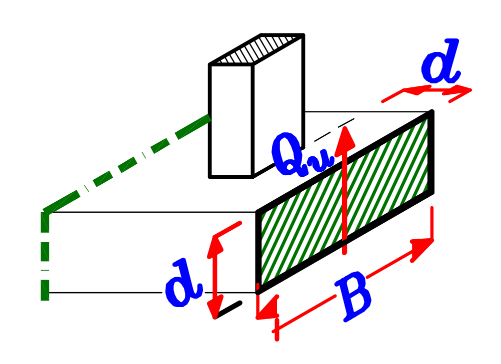
Critical section For Shear.



$$Q_{cr.} = Q_{max.} - w_{U.L.} * \frac{d}{2} = 1652.3 - 716.4 * \frac{0.83}{2} = 1355 \text{ kN}$$

* Calculate Actual shear stress. (q_u)

$$q_u = \frac{Q_{cr.}}{B * d} = \frac{1355 * 10^3}{1800 * 830} = 0.907 \text{ kN/m}^2$$



* Allowable shear stress. (q_{su})

$$q_{su} = 0.16\sqrt{\frac{F_{cu}}{\gamma_c}} = 0.16\sqrt{\frac{25}{1.5}} = 0.653 \text{ N/mm}^2$$

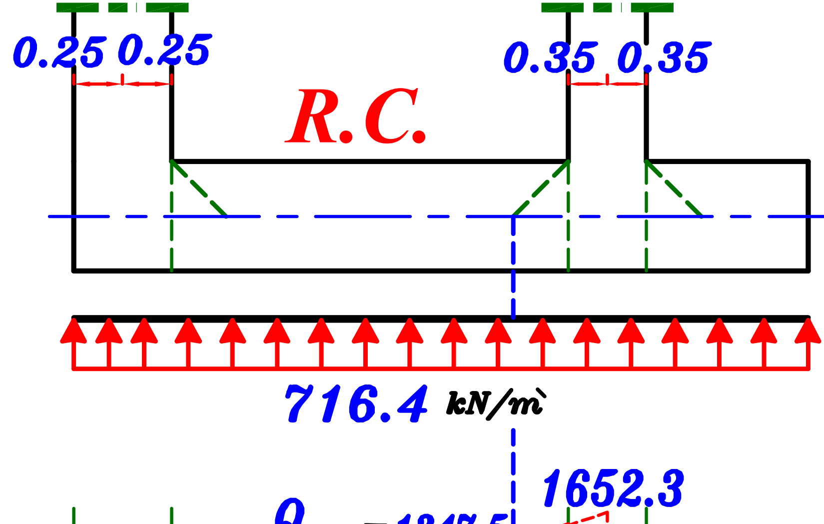
$q_u > q_{su}$ → UnSafe shear stresses

We have to increase Depth

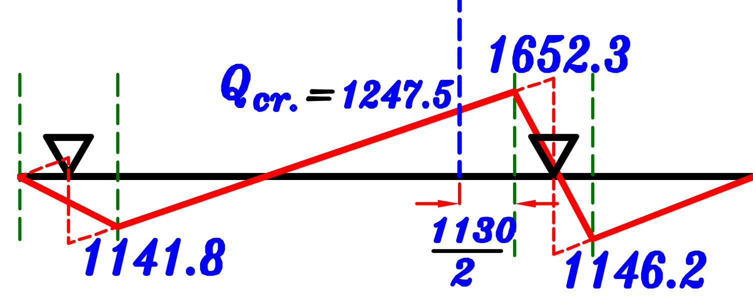
Increase the depth of the Footing.

لان q_u أكبر بكثير من q_{su} فمن المتوقع انه اذا تمت زياده ال depth ١٠ سم فقط فسيظل القطاع Unsafe shear لذا يفضل أن تكون الزياده كبيره

Take $t_{R.C.} = 1200$ mm $d = 1130$ mm

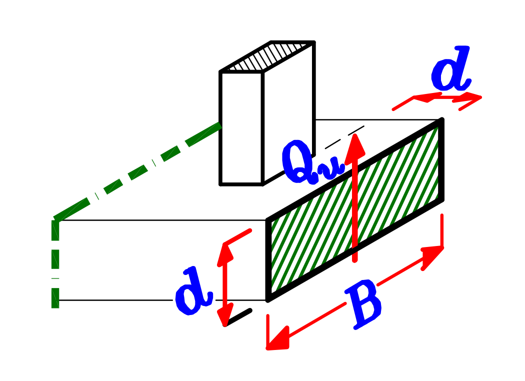


S.F.D.



$$Q_{cr.} = Q_{max.} - w_{U.L.} * \frac{d}{2} = 1652.3 - 716.4 * \frac{1.13}{2} = 1247.5 \text{ kN}$$

* Calculate Actual shear stress. (q_u)



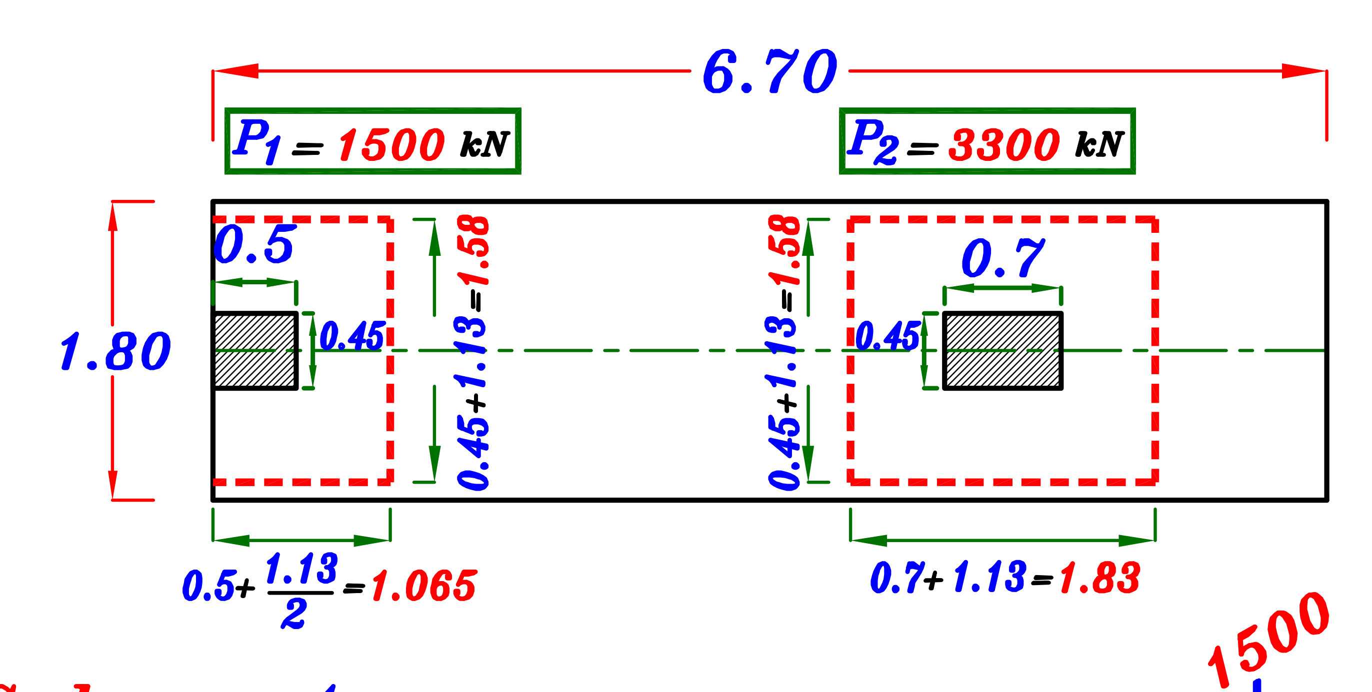
$$q_u = \frac{Q_{cr.}}{B * d} = \frac{1247.5 * 10^3}{1800 * 1130} = 0.613 \text{ kN/m}^2$$

* Allowable shear stress. (q_{su})

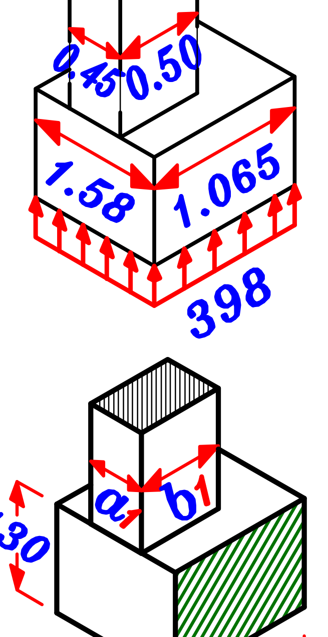
$$q_{su} = 0.16 \sqrt{\frac{F_{cu}}{\gamma_c}} = 0.16 \sqrt{\frac{25}{1.5}} = 0.653 \text{ N/mm}^2$$

$q_u < q_{su}$ ⟶ Safe shear stresses

4- Check Punching Shear. القص الثاقب .



Column 1



* Calculate Punching Force. (Q_{1p})

$$Q_{1p} = 1500 - 398 \ (1.065 * 1.58) = 830.3 \ kN$$

$$A_{1p} = \left[2\,(1065) + (1580)\right] * 1130$$

$$= 4192300 \ mm^2$$

* Calculate Actual Punching shear stress. q_{1pu}

$$q_{1pu} = \frac{830.3 * 10^3}{4192300} = 0.198 \ N/mm^2$$

Column2

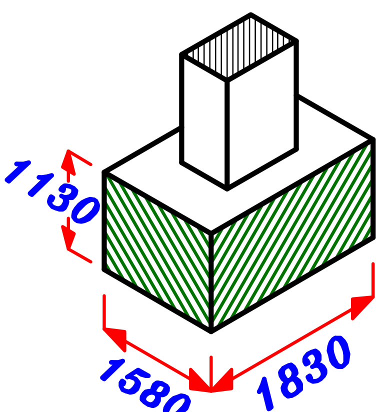
* **Calculate Punching Force.** (Q_{2p})

$$Q_{2p} = 3300 - 398\ (1.83 * 1.58)$$

$$= 2149.2\ kN$$

$$A_{2p} = [2(1580) + 2(1830)] * 1130$$

$$= 7706600\ mm^2$$



* **Calculate Actual Punching shear stress.** q_{1pu}

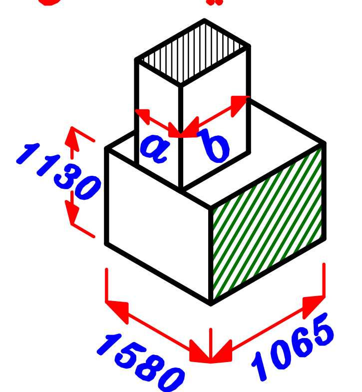
$$q_{2pu} = \frac{2149.2 * 10^3}{7706600} = 0.279\ N/mm^2$$

q_{pumax} the bigger q_{1pu} & $q_{2pu} = 0.279\ N/mm^2$

* **Calculate allowable Punching shear stress.** q_{pcu}

نأخذ القيمه الاقل من الاربع قيم التاليه .

$$q_{pcu} = 0.8\left(\frac{\alpha\, d}{b_o} + 0.2\right)\sqrt{\frac{F_{cu}}{\delta_c}}$$

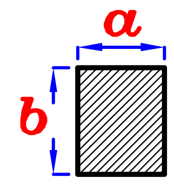


$$b_o = (a+d) + 2\left(b + \frac{d}{2}\right) = (450 + 1130) + 2\left(500 + \frac{1130}{2}\right) = 3710\ mm$$

$\alpha = 3$ as Edge Col.

$$q_{pcu} = 0.8\left(\frac{3 * 1130}{3710} + 0.2\right)\sqrt{\frac{25}{1.5}} = 3.63\ N/mm^2$$

$$q_{pcu} = 0.316\left(0.5 + \frac{a}{b}\right)\sqrt{\frac{F_{cu}}{\gamma_c}} \quad (N/mm^2)$$



$a = 0.45\ m$, $b = 0.50\ m$

$$q_{pcu} = 0.316\left(0.5 + \frac{0.45}{0.50}\right)\sqrt{\frac{25}{1.5}} = 1.80 \quad N/mm^2$$

$$q_{pcu} = 0.316\sqrt{\frac{F_{cu}}{\gamma_c}} = 0.316\sqrt{\frac{25}{1.5}} = 1.29\ N/mm^2$$

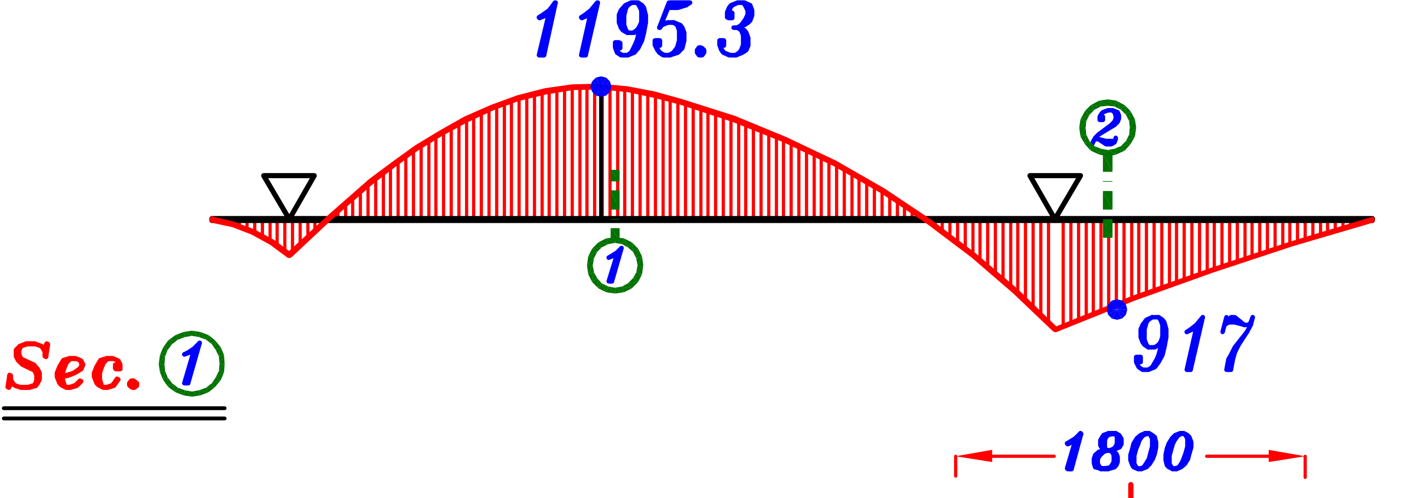
$$q_{pcu} = 1.60 \quad (N/mm^2)$$

$\therefore$ $q_{pcu} = 1.29 \quad N/mm^2$ نأخذ القيمه الاقل من الاربع قيم السابقه .

$$q_{pu_{max}} = 0.279 \quad N/mm^2$$

$q_{pu_{max}} \leqslant q_{p\,cu} \longrightarrow$ Safe punching shear.
No need to increase dimensions.

5- Reinforcement of the Footing.



Sec. (1)

1800

1130

1195.3 kN.m

$$1130 = C_1 \sqrt{\frac{1195.3 * 10^6}{25 * 1800}}$$

$$\longrightarrow C_1 = 6.93 \longrightarrow J = 0.826$$

$$A_s = \frac{M_{act.}}{J\ F_y\ d} = \frac{1195.3 * 10^6}{0.826 * 360 * 1130} = 3557.2\ mm^2$$

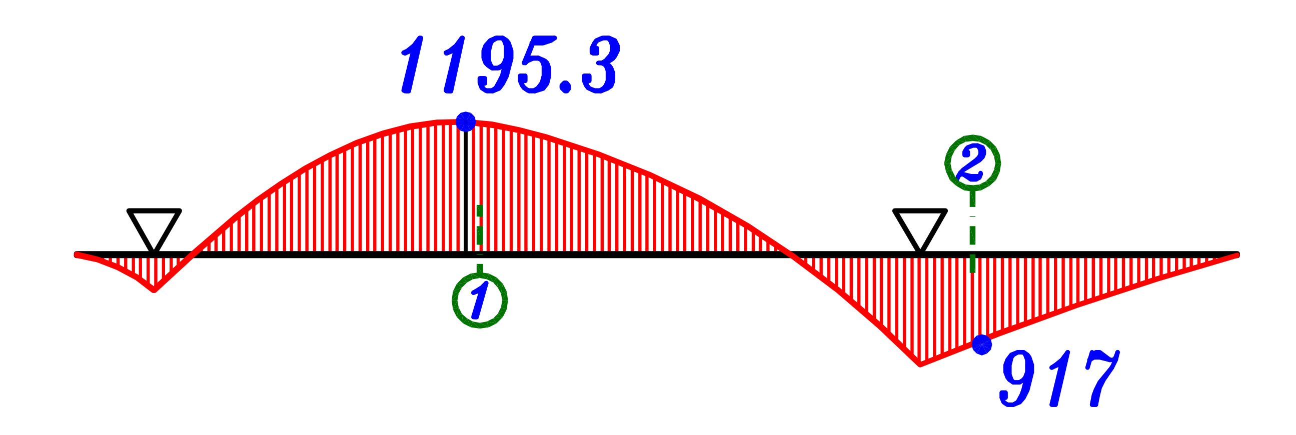
$$A_s\ (mm^2/m) = \frac{A_s}{B_{R.C.}} = \frac{3557.2}{1.80} = 1976.2\ mm^2/m'$$

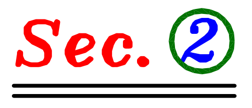
Check $A_{s_{min}}$

$$A_{s_{min}} = \begin{cases} 1.5\,d = 1.5 * 1130 = 1695 \\ 5 \phi 12/m' = 565.5 \end{cases} \quad 1395\ mm^2$$

$$\therefore A_s > A_{s_{min}} \longrightarrow \text{Take } A_s = 1976.2\ mm^2$$

$6 \phi 22/m'$





917 kN.m

1130

1800

$$1130 = C_1 \sqrt{\frac{917 * 10^6}{25 * 1800}}$$

$$\longrightarrow C_1 = 7.91 \longrightarrow J = 0.826$$

$$A_s = \frac{M_{act.}}{J\ F_y\ d} = \frac{917 * 10^6}{0.826 * 360 * 1130} = 2729.0\ mm^2$$

$$A_s\ (mm^2/m) = \frac{A_s}{B_{R.C.}} = \frac{2729.0}{1.80} = 1516.1\ mm^2/m'$$

Check $A_{s_{min}}$

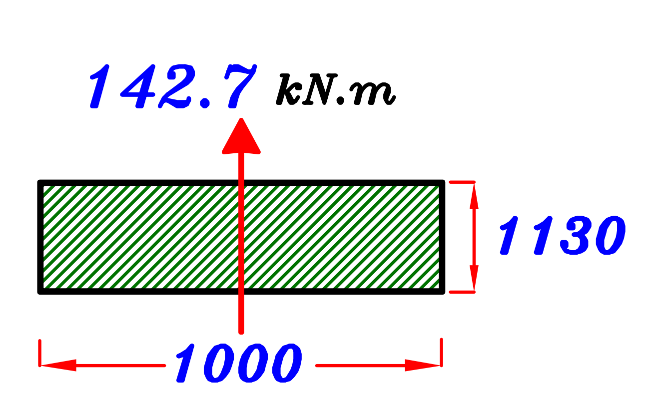
$$A_{s_{min}} = \begin{cases} 1.5\,d = 1.5 * 1130 = 1695 \\ 5 \phi 12/m' = 565.5 \end{cases} 1695\ mm^2$$

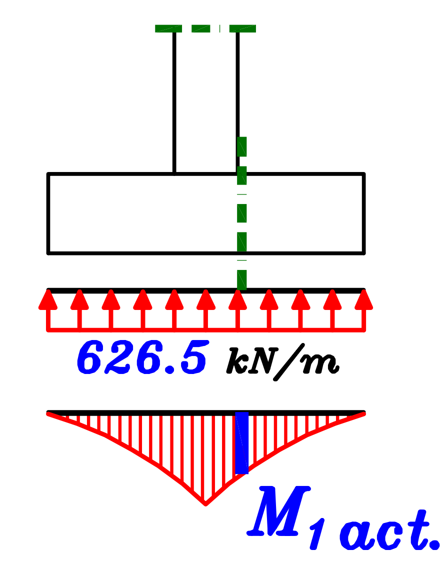
$$\therefore A_s < A_{s_{min}} \longrightarrow Take\ A_s = A_{s_{min}} = 1695\ mm^2$$

$5 \phi 22/m'$

Hidden Beam 1

$$M_{1act.} = 142.7 \text{ kN.m/m}$$





$$1130 = C_1 \sqrt{\frac{142.7 * 10^6}{25 \quad * 1000}} \longrightarrow C_1 = 14.9 \longrightarrow J = 0.826$$

$$A_s = \frac{M_{act.}}{J\, F_y\, d} = \frac{142.7 * 10^6}{0.826 * 360 * 1130} = 424.7 \; mm^2/m'$$

Check $A_{s_{min}}$

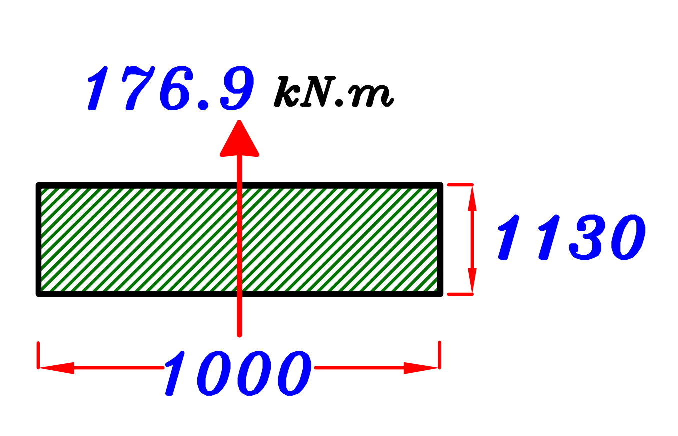
$$A_{s_{min}} = \left\{ \begin{array}{l} 1.5\, d = 1.5 * 1130 = 1695 \\ 5 \phi 12/m' = 565.5 \end{array} \right\} 1695 \; mm^2$$

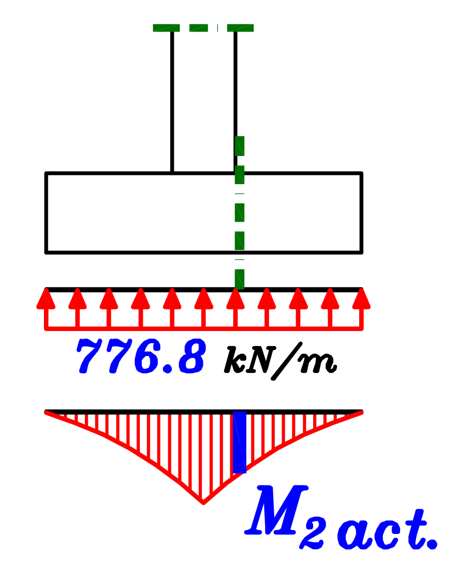
$$\therefore A_s < A_{s_{min}} \longrightarrow \text{Take } A_s = A_{s_{min}} = 1695 \; mm^2$$

$$7 \phi 18/m'$$

Hidden Beam 2

$$M_{2act.} = 176.9 \text{ kN.m/m}$$





$$1130 = C_1 \sqrt{\frac{176.9 * 10^6}{25 * 1000}} \longrightarrow C_1 = 13.4 \longrightarrow J = 0.826$$

$$A_s = \frac{M_{act.}}{J \, F_y \, d} = \frac{176.9 * 10^6}{0.826 * 360 * 1130} = 526.4 \ mm^2/m`$$

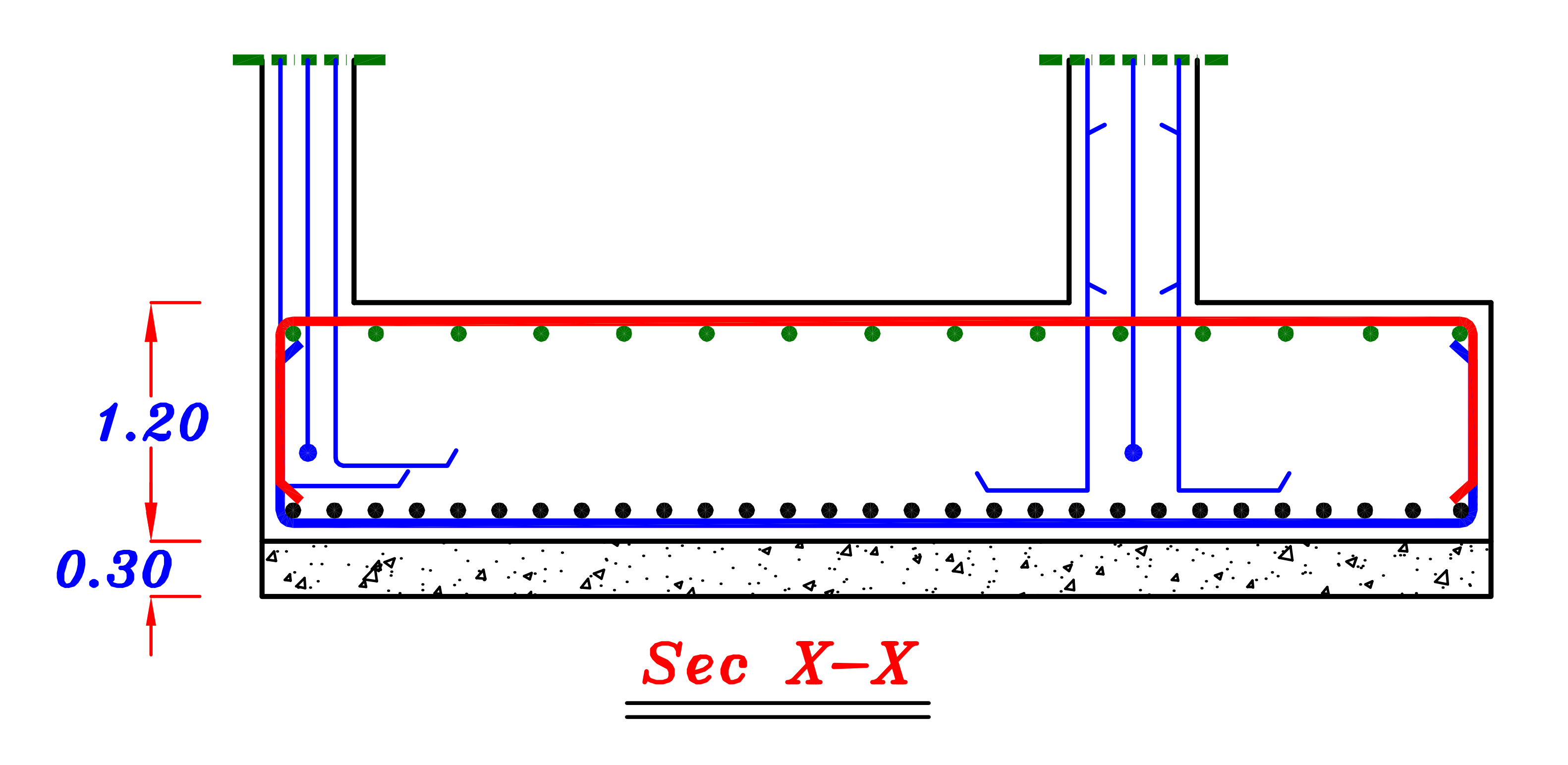
Check $A_{s_{min}}$

$$A_{s_{min}} = \begin{cases} 1.5\, d = 1.5 * 1130 = 1695 \\ 5 \phi 12/m` = 565.5 \end{cases} 1695 \ mm^2$$

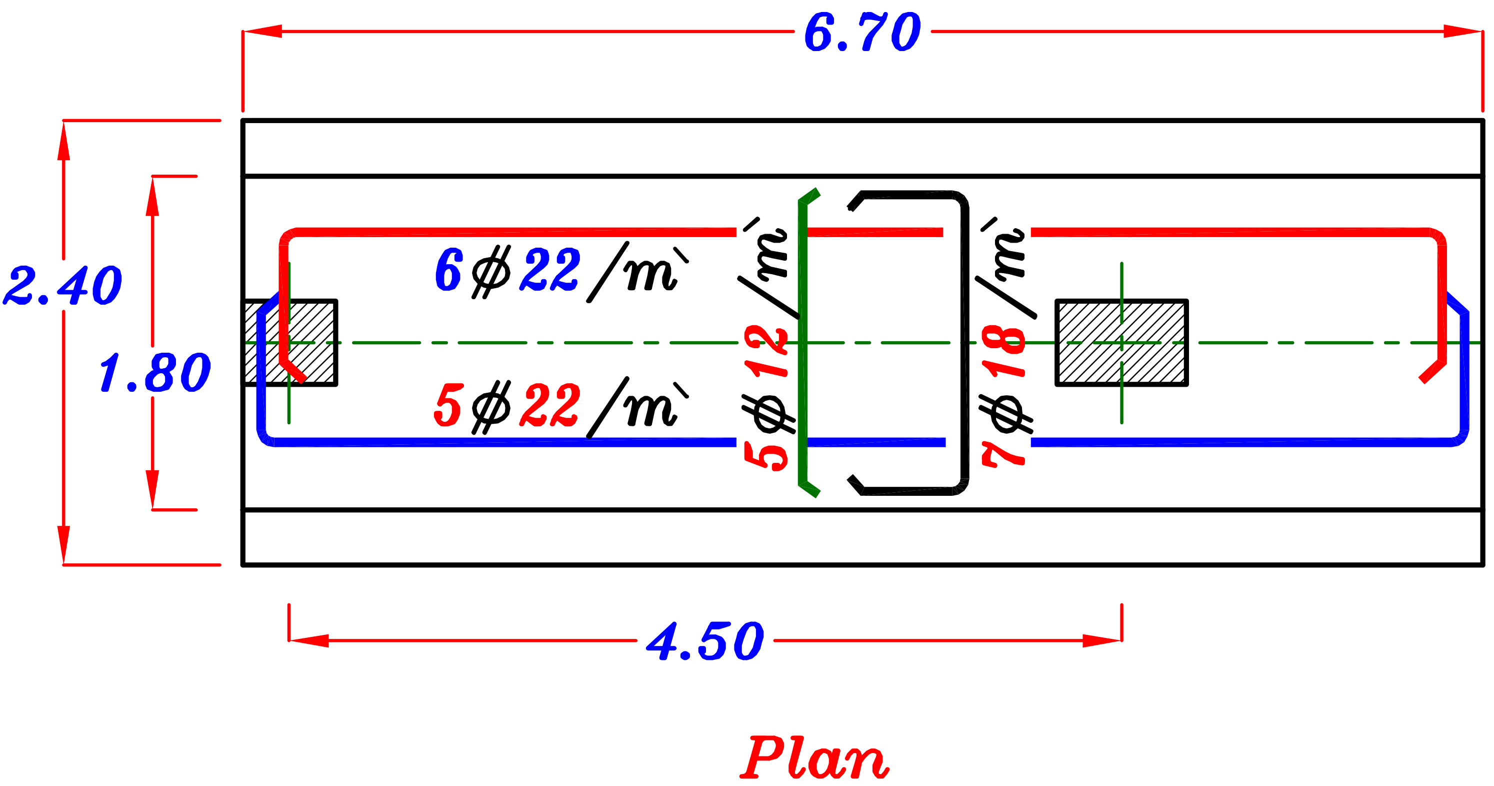
$$\therefore A_s < A_{s_{min}} \longrightarrow \text{Take } A_s = A_{s_{min}} = 1695 \ mm^2$$

$7 \phi 18/m`$

6- Details of Reinforcement.



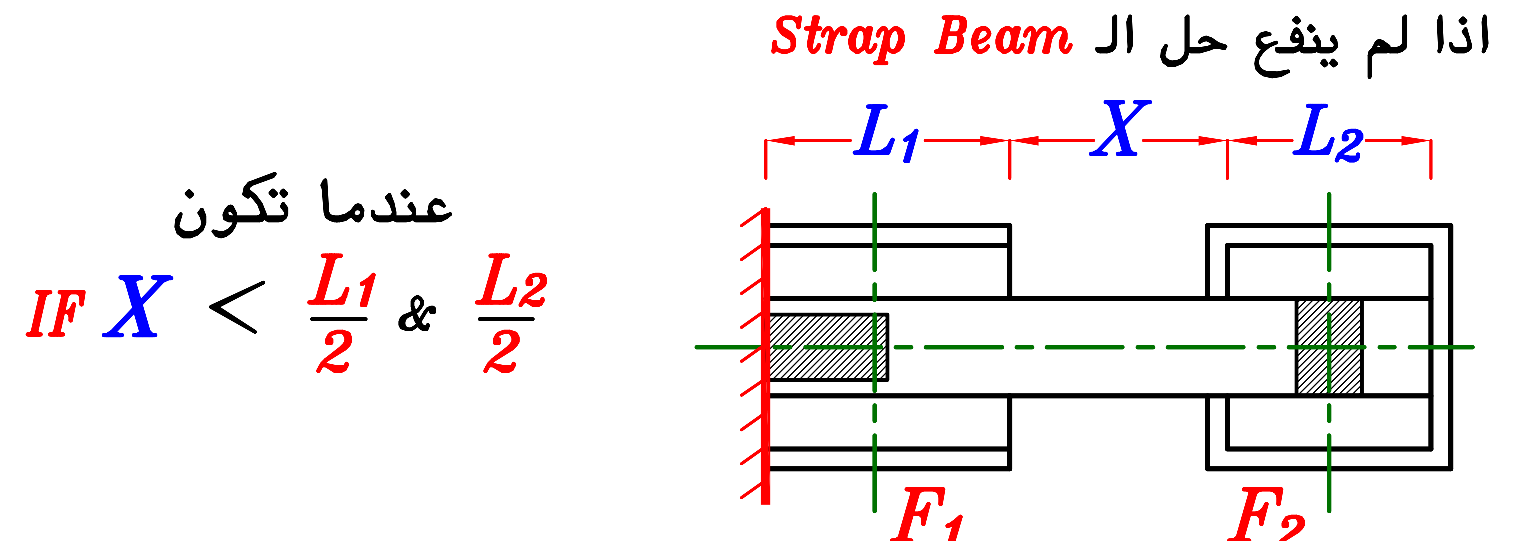
Sec X-X



Plan



b Trapezoidal Combined Footing. $P_1 > P_2$ حالة نادرة .



IF $P_1 > P_2$ use Trapezoidal combined Footing.

P_1

P_2

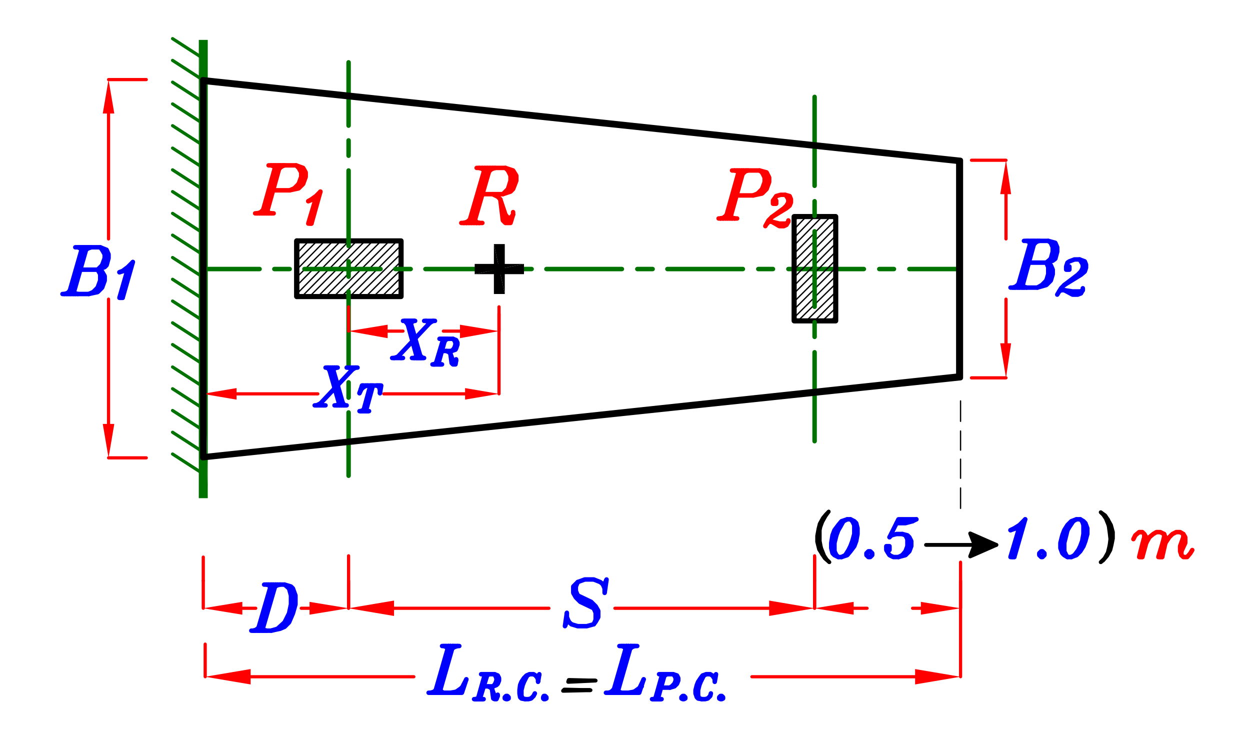
B_1

B_2

S

$L_{R.C.} = L_{P.C.}$

1 – Calculate the Footing area. (Width & Length of R.C. Footing.)



يتم تحديد طول القاعده

$$L_{R.C.} = L_{P.C.} = D + S + (0.5 \rightarrow 1.0)\, m$$

حيث D هى المسافه من منتصف عمود الجار الى حد الجار .

و S هى المسافه بين منتصف العمودين .

يتم حساب قيمه محصله الاحمال R

$$R = P_1 + P_2$$

يتم تحديد بعد محصله الاحمال X_R عن منتصف عمود الجار .

$$R * X_R = P_2 * S \longrightarrow X_R = \frac{P_2}{R} * S$$

يتم تحديد بعد محصله الاحمال X_T عن حد الجار .

$$X_T = X_R + D$$

Calculate the width of the Footing. B

IF $t_{P.C.} \geq 20\ cm$

$$A_{P.C.} = \frac{R_w}{q_{all}} = \checkmark\ m^2 = L_{P.C.}\left(\frac{B_{1P.C.} + B_{2P.C.}}{2}\right) \quad \text{------} (1)$$

$$X_T = \frac{L_{P.C.}}{3}\left(\frac{B_{1P.C.} + 2B_{2P.C.}}{B_{1P.C.} + B_{2P.C.}}\right) \quad \text{------} (2)$$

مكان محصله شبه المنحرف

From (1) , (2) → $B_{1P.C.} = \checkmark$ & $B_{2P.C.} = \checkmark$

$B_{1R.C.} = B_{1P.C.} - 2\,t_{P.C.}$

$B_{2R.C.} = B_{2P.C.} - 2\,t_{P.C.}$

IF $t_{P.C.} < 20\ cm$

$$A_{R.C.} = \frac{R_w}{q_{all}} = \checkmark\ m^2 = L_{R.C.}\left(\frac{B_{1R.C.} + B_{2R.C.}}{2}\right) \quad \text{------} (1)$$

$$X_T = \frac{L_{R.C.}}{3}\left(\frac{B_{1R.C.} + 2B_{2R.C.}}{B_{1R.C.} + B_{2R.C.}}\right) \quad \text{------} (2)$$

From (1) , (2) → $B_{1R.C.} = \checkmark$ & $B_{2R.C.} = \checkmark$

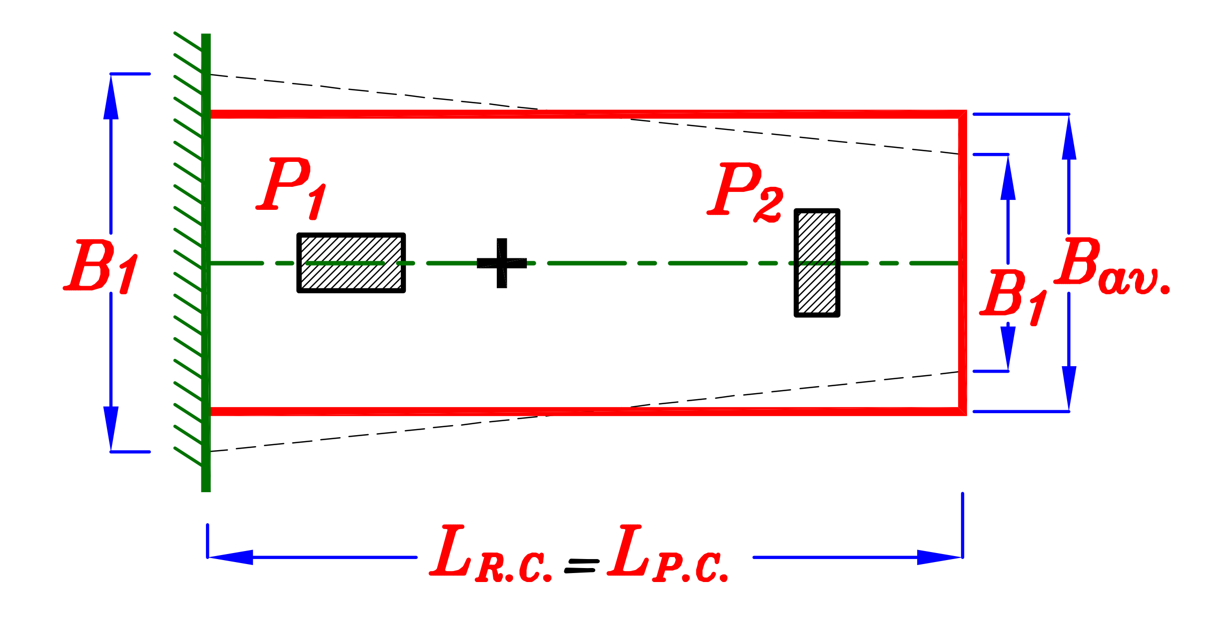
$B_{1P.C.} = B_{1R.C.} + 2\,t_{P.C.}$

$B_{2P.C.} = B_{2R.C.} + 2\,t_{P.C.}$

Calculate the average width of the Footing.

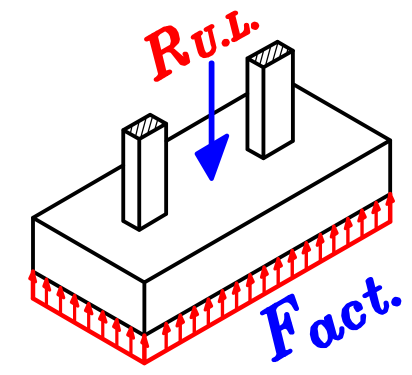
$(B_{av.R.C.} * L_{R.C.})$ نعتبر أن القاعده الشبه منحرف عباره عن مستطيل أبعاده

$$B_{av.R.C.} = \frac{B_{1\,R.C.} + B_{2\,R.C.}}{2}$$



– Actual Normal stress on R.C. Footing (U.L.)

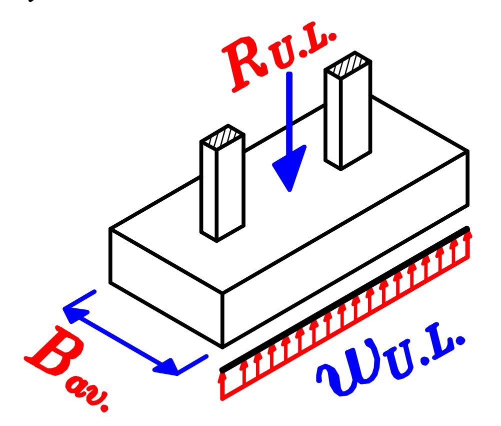
$$F_{act.} = \frac{R_{U.L.}}{B_{av.\,R.C.} * L_{R.C.}} \quad (kN/m^2)$$



– Actual Uniform Load on R.C. Footing (U.L.) as a beam.

$B_{R.C.}$ نعتبر أن القاعده عباره عن كمره بعرض

$$w_{U.L.} = \frac{R_{U.L.}}{L_{R.C.}} \quad (kN/m`)$$

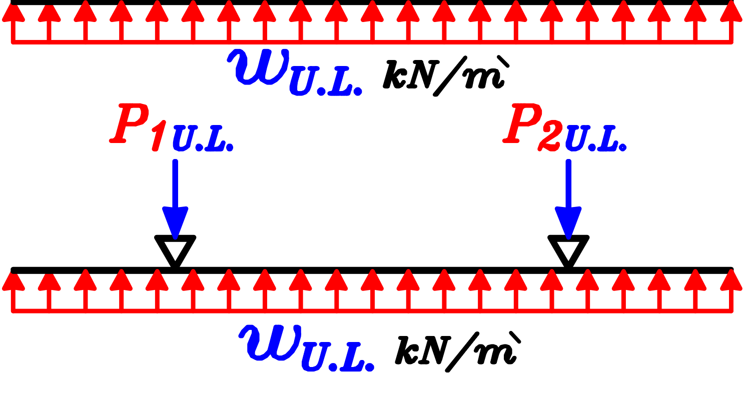


Drawing U.L. B.M.D. & S.F.D. on the all R.C. Footing.

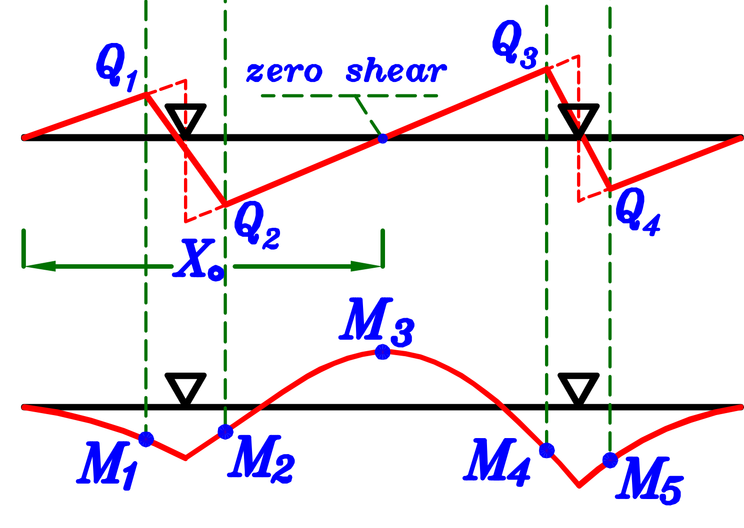
Longitudinal direction.

نعتبر أن القاعده عباره عن كمره بعرض $B_{R.C.}$

يتم رسم S.F.D. ، B.M.D. للقاعده كلها كأنها كمره بعرض $B_{R.C.}$



و يتم حساب قيم S.F. ، B.M. على وش الاعمده .



لتحديد أكبر moment فى منتصف القاعده M_3

يتم تحديد مكان نقطه zero shear أى حساب المسافه X_o

$P_{1U.L.} = w_{U.L.} * X_o$ → $X_o = \checkmark$ → $M_3 = \checkmark$

$M_{max.}$ is the bigger moment of M_1, M_2, M_3, M_4 & M_5

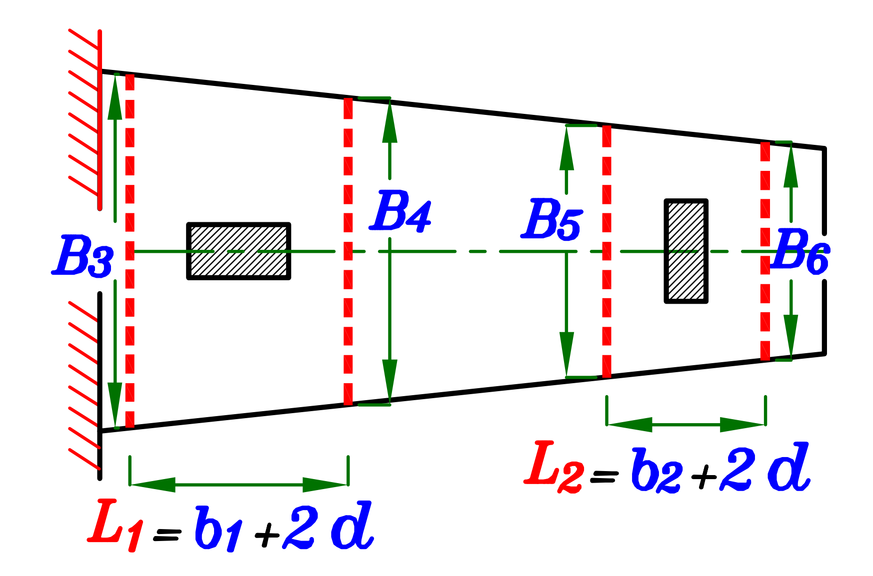
$$d_{(mm)} = C_1 \sqrt{\frac{M_{max}(kN.m) * 10^6}{F_{cu}(N/mm^2) * B_{av.R.C.}(mm)}}$$

Choose $C_1 = (3.5 \rightarrow 5.0)$ Get $d = \checkmark\checkmark$ (mm)

$$t_{R.C.} = d + cover \ (70 \ mm)$$

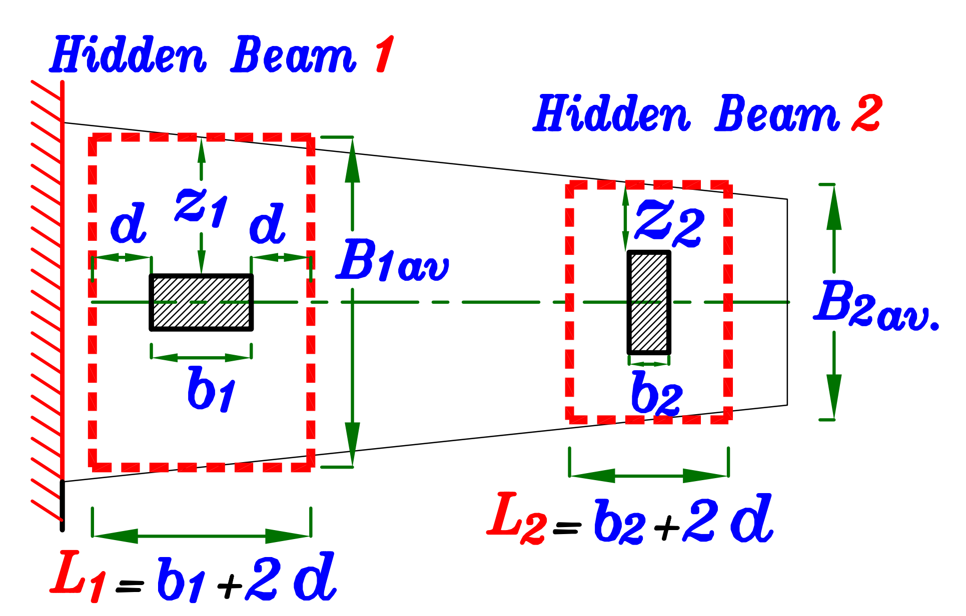
Check depth in Transverse direction. Short direction.

As a Hidden Beam.



$$B_{1av.} = \frac{B_3 + B_4}{2}$$

$$B_{2av.} = \frac{B_5 + B_6}{2}$$



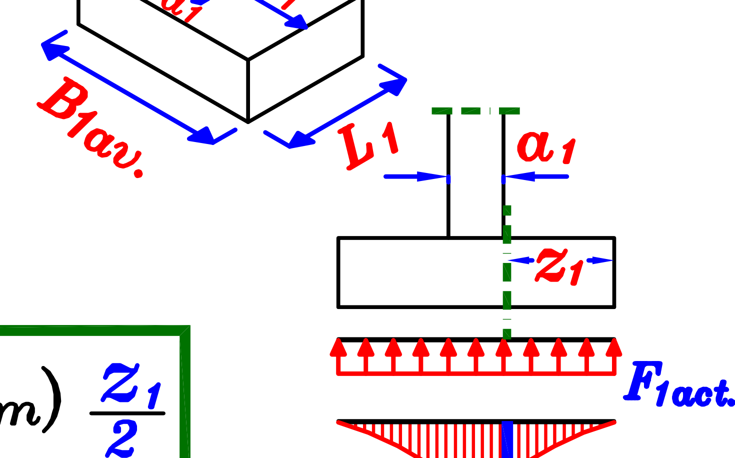
Hidden Beam 1

$$F_{1act.} = \frac{P_{1U.L.}}{B_{1av} * L_1}$$ (kN/m^2)

$$Z_1 = \frac{B_{1av} - a_1}{2}$$ (m)

$$M_{1act.} = (F_{1act.} * Z_1 * 1.0m)\ \frac{Z_1}{2}$$

$(kN.m/1.0m)$



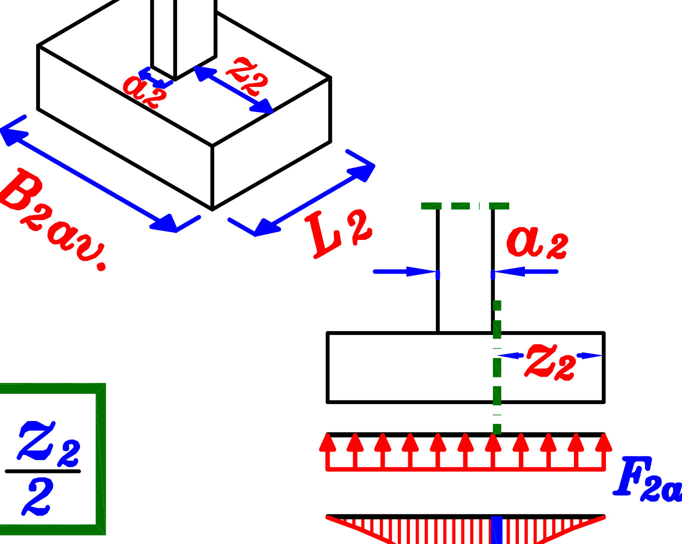
Hidden Beam 2

$$F_{2act.} = \frac{P_{2U.L.}}{B_{2av} * L_2}$$ (kN/m^2)

$$Z_2 = \frac{B_{2av} - a_2}{2}$$ (m)

$$M_{2act.} = (F_{2act.} * Z_2 * 1.0m)\ \frac{Z_2}{2}$$

$(kN.m/1.0m)$



Choose M_{bigger} The bigger value of $M_{1act.}$ & $M_{2act.}$

$$d = C_1 \sqrt{\frac{M_{bigger} * 10^6}{F_{cu} * 1000}} \xrightarrow{\text{Get}} C_1$$

Then Check on $C_1 \nless 3.0$

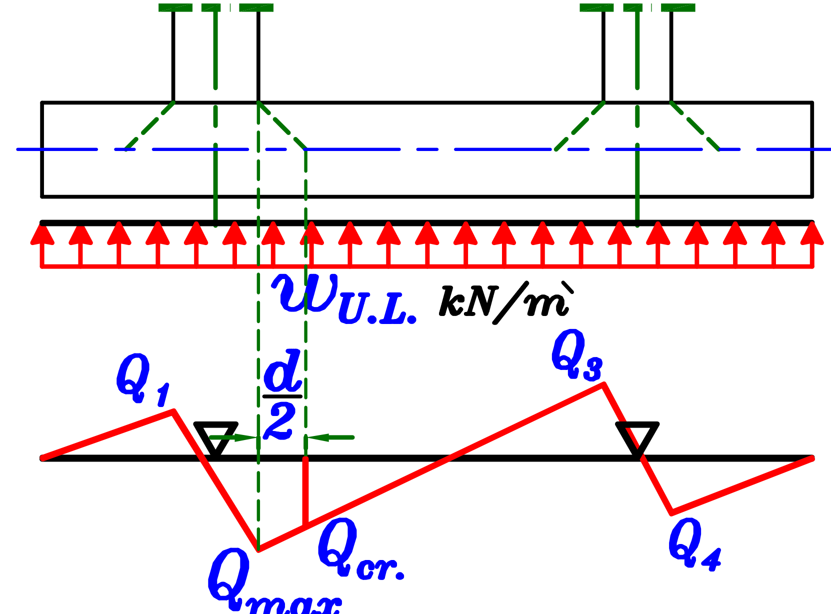
IF $C_1 < 3.0$ ⟶ Increase d

and Recheck the transverse direction.

3 – Check Shear at long direction.

Critical section For Shear.

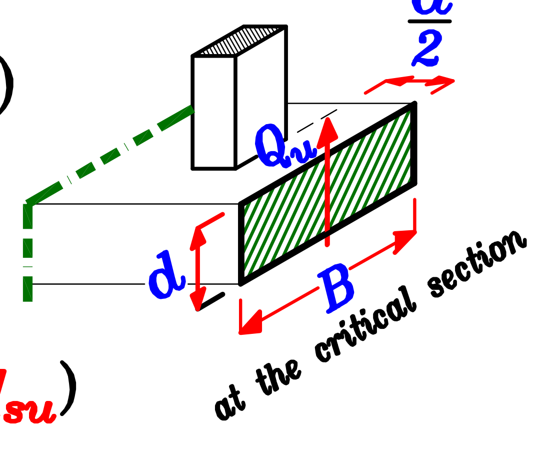
على بعد $\frac{d}{2}$ من وش العمود اللى عنده $Q_{max.}$



$$Q_{cr.} = Q_{max.} - w_{U.L.} * \frac{d}{2}$$

* Calculate Actual shear stress. (q_u)

$$q_u = \frac{Q_{cr.}\,(kN) * 10^3}{B\,(mm) * d\,(mm)} \quad (N/mm^2)$$



* Calculate Allowable shear stress. (q_{su})

$$q = 0.16 \sqrt{\frac{F_{cu}}{\gamma_c}} \quad (N/mm^2)$$

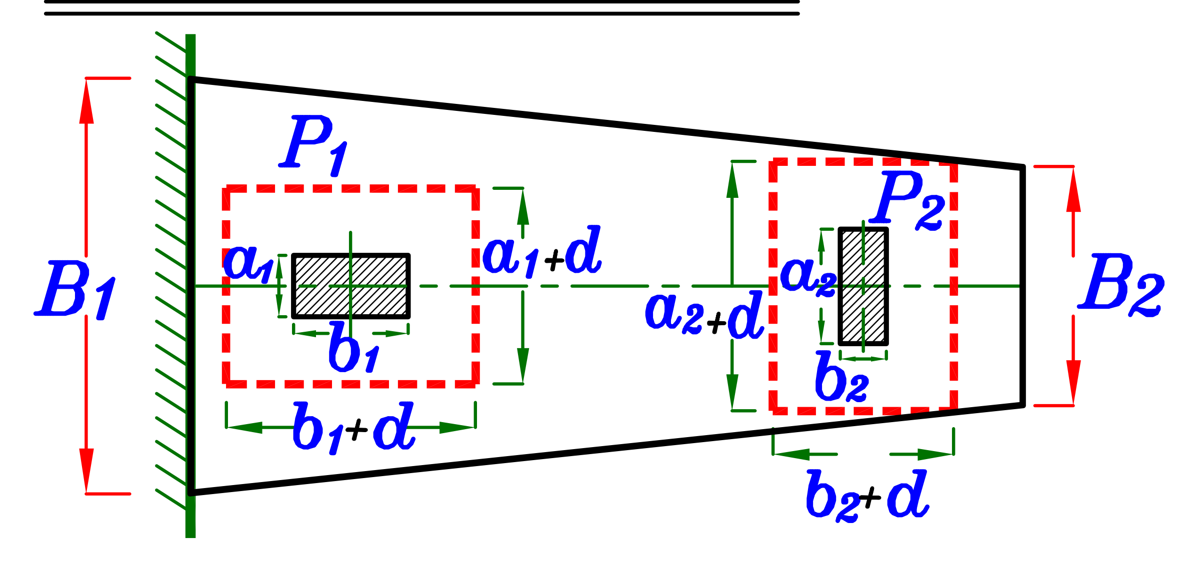
* Compare between

Actual shear stress (q_u) & Allowable shear stress (q_{su})

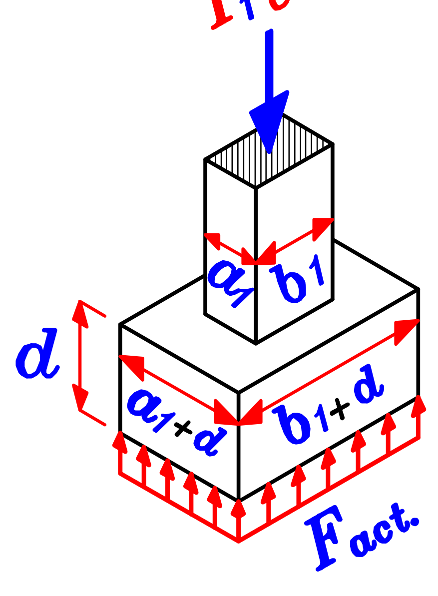
* IF $q_u \leqslant q_{su}$ ⟶ Safe shear stresses
  No need to increase dimensions.

* IF $q_u > q_{su}$ ⟶ UnSafe shear stresses
  We have to increase dimensions.

4 – Check Punching Shear. القص الثاقب .



Column 1



* **Calculate Punching Force.** (Q_{1p})

$$Q_{1p} = P_{1\,U.L.} - (F_{act.})\left[(a_1+d)(b_1+d)\right]$$

(kN)

* **Calculate Punching shear area.** (A_{1p})

المحيط   العمق

$$A_{1p} = \left[2(a_1+d)+2(b_1+d)\right] * d$$

(mm^2)

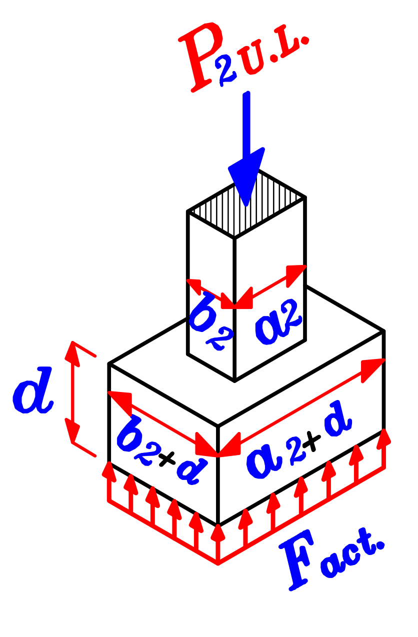
* **Calculate Actual Punching shear stress.** q_{1pu}

$$q_{1pu} = \frac{Q_{1p}\ (kN) * 10^3}{\left[2(a_1+d)+2(b_1+d)\right] * d\ (mm^2)}$$

(N/mm^2)

Column 2

* Calculate Punching Force. (Q_{2p})



$$Q_{2p} = P_{2\,U.L.} - (F_{act.})\left[(a_2+d)(b_2+d)\right]$$

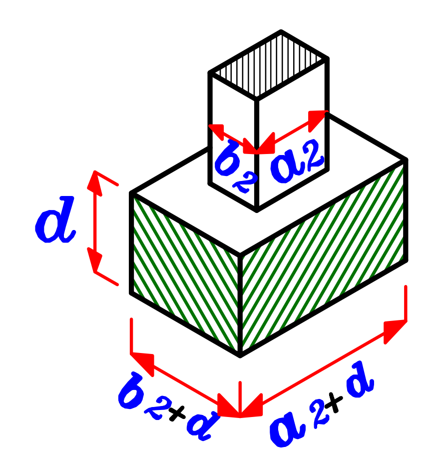
(kN)

* Calculate Punching shear area. (A_{2p})

المحيط العمق

$$A_{2p} = \left[2(a_2+d) + 2(b_2+d)\right] * d$$

(mm^2)



* Calculate Actual Punching shear stress. q_{2pu}

$$q_{2pu} = \frac{Q_{2p}\,(kN) * 10^3}{\left[2(a_2+d) + 2(b_2+d)\right] * d\ (mm^2)}$$

(N/mm^2)

Choose $q_{pu_{max}}$ the bigger value of q_{1pu} & q_{2pu}

* **Calculate allowable Punching shear stress. q_{pcu}**

نأخذ القيمه الاقل من الاربع قيم التاليه .

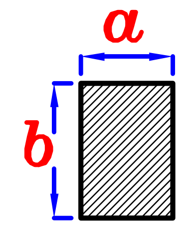
$$q_{pcu} = 0.8\left(\frac{\alpha\, d}{b_o} + 0.2\right)\sqrt{\frac{F_{cu}}{\gamma_c}}$$

$\alpha = 4$ Interior Col.
$\alpha = 3$ Edge Col.
$\alpha = 2$ Corner Col.

Take b_o For the Edge column to get smaller q_{pcu}

Take $\alpha = 3$ For the Edge column to get smaller q_{pcu}

$$q_{pcu} = 0.316\left(0.5 + \frac{a}{b}\right)\sqrt{\frac{F_{cu}}{\gamma_c}} \quad (N/mm^2)$$



a هو العرض الصغير للعمود

$$q_{pcu} = 0.316\sqrt{\frac{F_{cu}}{\gamma_c}} \quad (N/mm^2)$$

$$q_{pcu} = 1.60 \quad (N/mm^2)$$

* **Compare between**

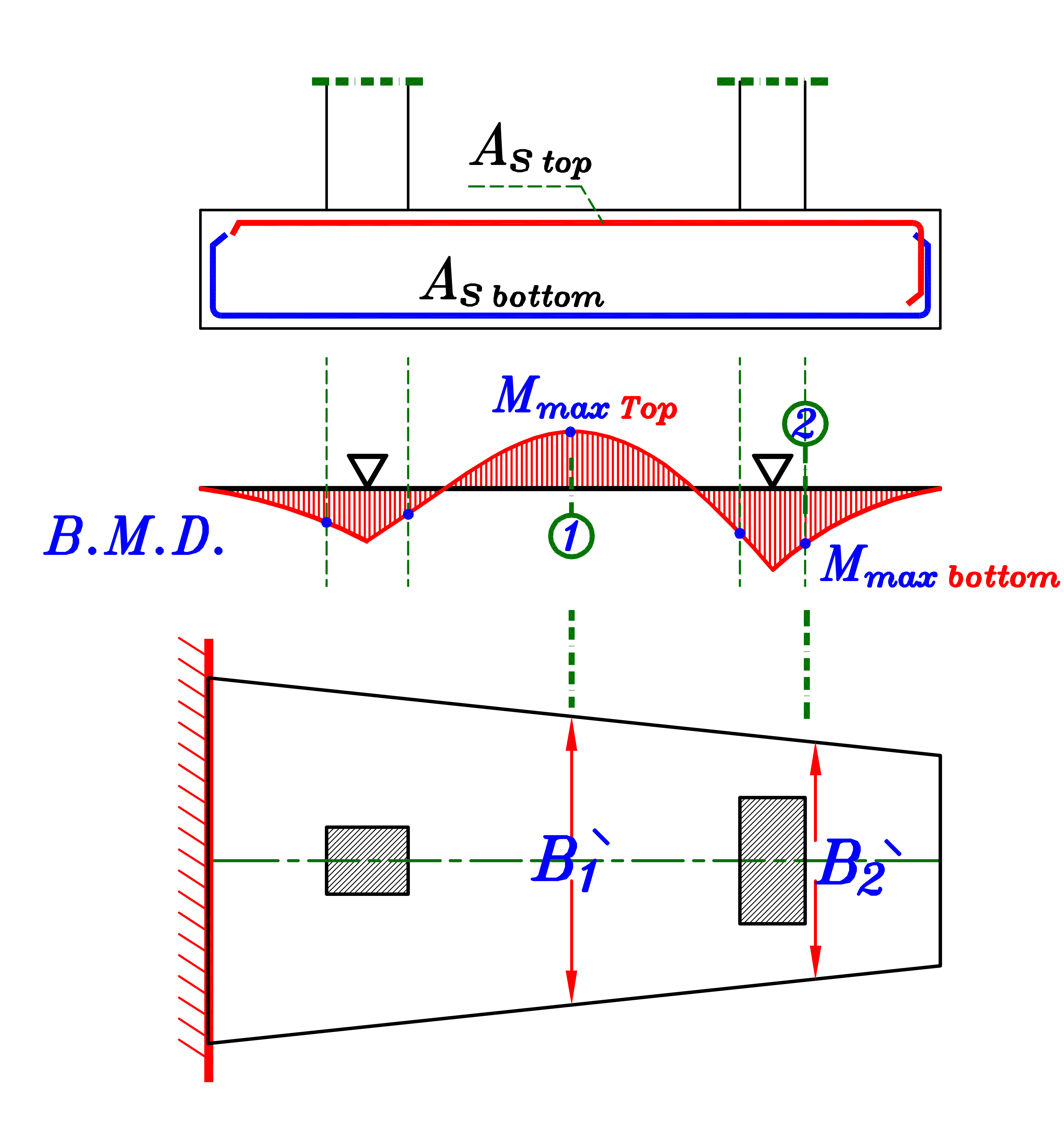
Actual punching shear stress ($q_{pu_{max}}$) & Allowable punching shear stress (q_{pcu})

* IF $q_{pu_{max}} \leqslant q_{pcu}$ ⟶ Safe punching shear. No need to increase dimensions.

* IF $q_{pu_{max}} > q_{pcu}$ ⟶ UnSafe punching shear. We have to increase dimensions.

5- Reinforcement of the Footing.

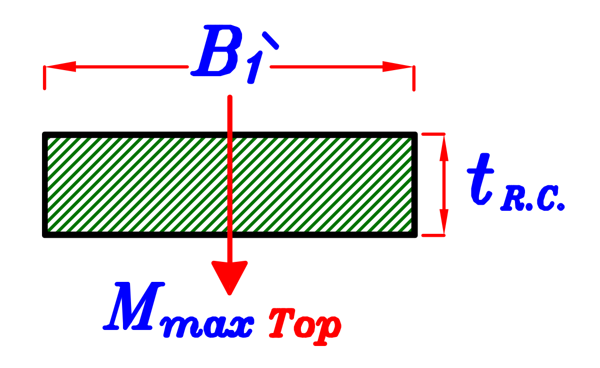
Longitudinal direction.



Sec. ①

From $d = C_1 \sqrt{\dfrac{M_{max\ Top}}{F_{cu} * B_1`}}$

$\xrightarrow{Get} C_1 \longrightarrow J$



Get $\boxed{As_{top} = \dfrac{M_{max\ Top}}{J\ F_y\ d}}$ (mm^2)

Check As_{min} $\boxed{As_{min}\ (mm^2/m) = \begin{cases} 1.5\ d\ (mm) \\ 5 \phi 12 / m` \end{cases}}$ الأكبر

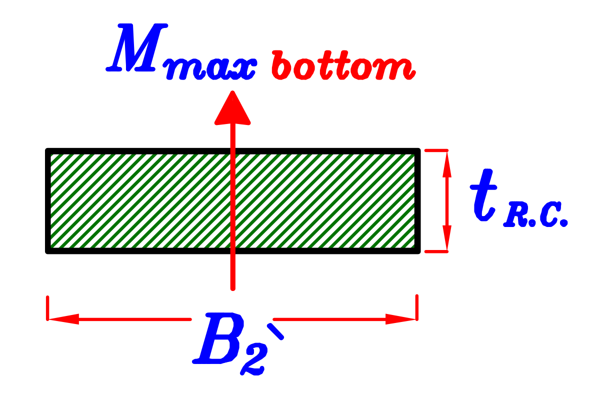
IF $As_{top} \geqslant As_{min} \longrightarrow$ o.k.

IF $As_{top} < As_{min} \longrightarrow$ Take $As = As_{min}$

Sec. ②

From $d = C_1 \sqrt{\dfrac{M_{max\ bottom}}{F_{cu} * B_2`}}$

$\xrightarrow{Get} C_1 \longrightarrow J$



Get $\boxed{As_{bott} = \dfrac{M_{max\ bottom}}{J\ F_y\ d}}$ (mm^2)

Check As_{min} $\boxed{As_{min}\ (mm^2/m) = \begin{cases} 1.5\ d\ (mm) \\ 5 \phi 12 / m` \end{cases}}$ الأكبر

IF $As_{bott} \geqslant As_{min} \longrightarrow$ o.k.

IF $As_{bott} < As_{min} \longrightarrow$ Take $As = As_{min}$

Transverse direction. Short direction.

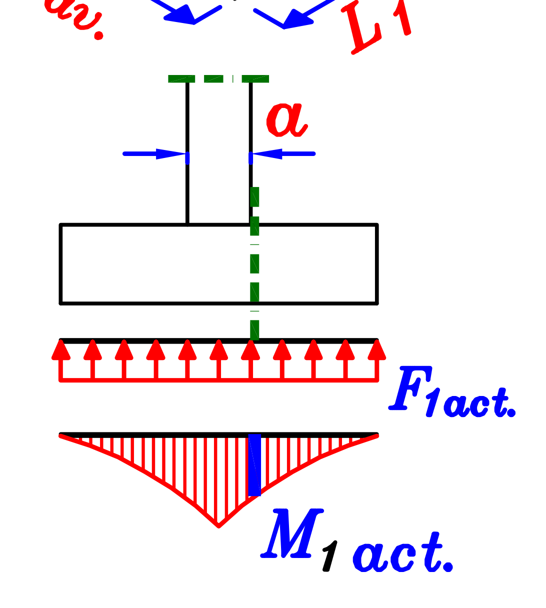
Hidden Beam 1

From $d = C_1 \sqrt{\dfrac{M_{1act.}}{F_{cu} * 1000}}$

$\xrightarrow{Get} C_1 \longrightarrow J$

Get $$A_{s1} = \frac{M_{1act.}}{J\ F_y\ d} \quad (mm^2/m`)$$

Check $A_{s\,min}$



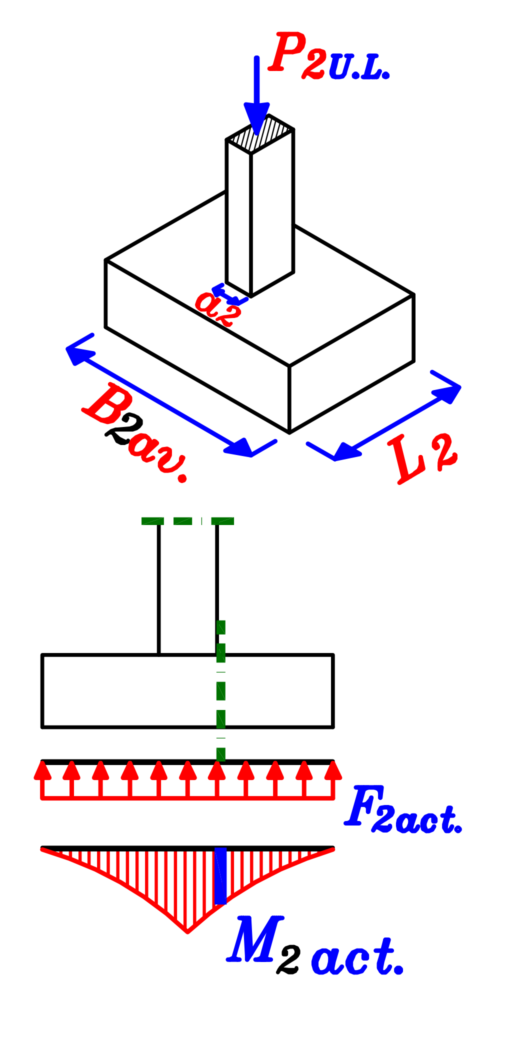
Hidden Beam 2

From $d = C_1 \sqrt{\dfrac{M_{2act.}}{F_{cu} * 1000}}$

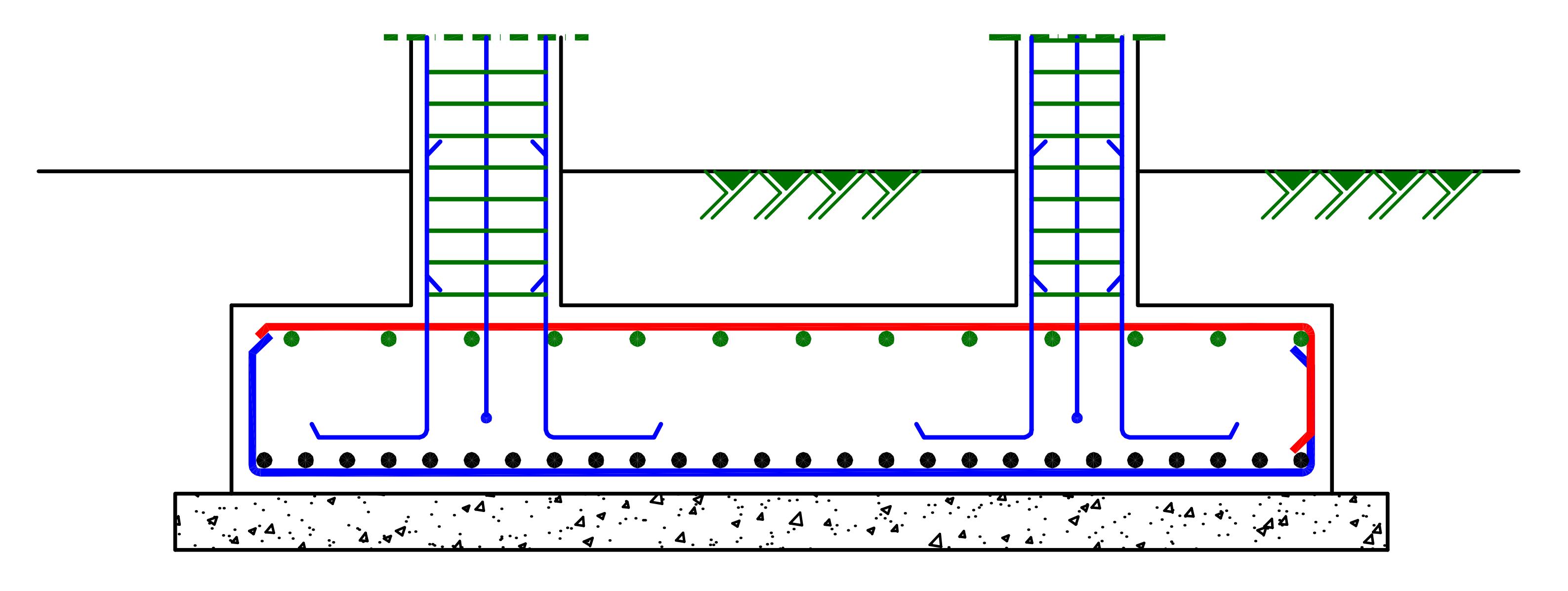
$\xrightarrow{Get} C_1 \longrightarrow J$

Get $$A_{s2} = \frac{M_{2act.}}{J\ F_y\ d} \quad (mm^2/m`)$$

Check $A_{s\,min}$



6- Details of Reinforcement.



Sec X-X

X

X

A_{s1}

$5\phi12/m'$

A_{s2}

L_1

L_2

Plan